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TRANSACTIONS

OF THE

AMERICAN CERAMIC SOCIETY

CONTAINING THE PAPERS AND DISCUSSIONS

OF THE

SIXTH ANNUAL MEETING

HELD AT

CINCINNATI, OHIO

FEBRUARY 1st to 3rd, 1904

The Society is not, as an organization, responsible for the statements of fact or opinion expressed in its papers and discussions.

PUBLISHED BY THE SOCIETY
SECRETARY'S OFFICE COLUMBUS, OHIO
December 15, 1904

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OFFICERS.

FOR THE YEAR ENDING FEBRUARY, 1904.

President,

FRANCIS W. WALKER, - - - Beaver Falls, Pa.

Vice President,

ALBERT V. BLEININGER, B. Sc., - - - Columbus, O.

Secretary,

EDWARD ORTON, Jr., E. M., - - - Columbus, O.

Treasurer,

STANLEY G. BURT, - - - - Cincinnati, O.

Managers,

ADOLPH F. HOTTINGER, - - - - Chicago, Ills.

Term Expires, 1905.

ELMER E. GORTON, - - - - New York, N. Y.

Term Expires, 1906.

EDWARD C. STOVER, - - - - Trenton, N. J.

Term Expires, 1907.

HONORARY MEMBERS.

Mrs. Maria Longworth Storer.
(Mrs. Bellamy Storer)
Cincinnati, Ohio.

FOREIGN MEMBERS.

Zimmer, William H., Ph. D., Coburg, Germany.	Redaction Sprechsaal.

RESIDENT MEMBERS.

Barringer, Lawrence E., E. M. Schenectady, N. Y.	Research Chemist, General Electric Company.
Binns, Charles F., Alfred, N. Y.	Director New York State School of Clayworking and Ceramics.
Bleininger, Albert V., B. Sc., Columbus, Ohio.	Instructor in Ceramics, Ohio State University.
Burt, Stanley G., Cincinnati, Ohio.	Rookwood Pottery Company.
Cannan, William, Jr., Syracuse, N. Y.	Onondaga Pottery Company.
Cushman, Allerton S., A.M., Ph.D., Washington, D. C.	Chemist Road Material Laboratory Department of Agriculture.
Fickes, Walter M., E. M., Carnegie, Pa.	Manager, Rosslyn Brick Company.
Fiske, J. Parker, B. S., Boston, Mass.	Fiske Brick Company, Dover Point, N. H.
Gates, William D., Chicago, Ill.	American Terra Cotta and Ceramic Company.
Geijsbeek, Samuel, Cheltenham, St. Louis, Mo.	Winkle Terra Cotta Company.
Gorton, Elmer E., 7-E. 42nd St., N. Y.	General Manager, W. A. Underhill Brick Company.
Hart, Edward, Ph. D., Easton, Pa.	Professor of Chemistry, LaFayette College.
Hensel, Otto, St. Louis, Mo.	Parker-Russel Mining and Manufacturing Company.
Hottinger, Adolph F., Chicago, Ill.	Northwestern Terra Cotta Co.
Hull, Walter A.. E. M. Shawmut, Pa., Elk Co.	Manager Shawmut Clay Manufacturing Company.

Langenbeck, Karl, 508 Broome St., New York City.	
Lovejoy, Ellis, E. M., Columbus, Ohio.	
Mayer, Ernest, Beaver Falls, Pa.	Mayer Pottery Company.
Ogle, Earl, McK., Indianapolis, Ind.	United States Encaustic Tile Works.
Orton, Edward, Jr., E. M., Columbus, Ohio.	Director, Department of Ceramics, Ohio State University.
Pass, James, Syracuse, N. Y.	Onondaga Pottery Company.
Peppel, Samuel Vernon, B. Sc. Louisville, Ky.	Editorial Staff, "Rock Products."
Purdy, Ross C., Columbus, Ohio.	Assistant in Ceramics, Ohio State University.
Richardson, Willard D., A. M. Columbus, Ohio.	Consulting Engineer to the Brick Industry.
Ries, Heinrich, Ph. D., Ithaca, N. Y.	Associate Professor of Economic Geology, Cornell University.
Stover, Edward C., Trenton, N. J.	Trenton Potteries Company.
Walker, Francis W., Beaver Falls, Pa.	Beaver Falls Art Tile Company.
Watts, Arthur S., Victor, N. Y.	Ceramic Engineer, The Locke Insulator Manufacturing Company.
Wheeler, Herbert A., E. M., 721 Olive St., St. Louis, Mo.	Consulting Engineer, Mining Metallurgical and Ceramic Work.

FOREIGN ASSOCIATE MEMBERS.

Briegleb, Otto Wilh. Gustav, Amsterdam, Holland.	Manufacturer of Earthenware.
Carter, Owen, "Wykeham." Poole, England.	Carter Encaustic Tile Works.
Cieszewski, Joseph, Warsaw, Poland.	
Cobb, John W., Leeds, Yorkshire, England.	Director, Farnley Iron Company.
De Luze, Henri, Avenue de Poitiers, Limoges, France.	Inginieur des Arts and Manufacture Theo. Haviland, Porcelain M'f'y.
Fredrickson, Nils, Svedala, Sweden.	Director, Ceramic School.
Jenkins, Newell Sill, D.D.S., K.S. Walpurgis Strasse 15. Dresden, Germany.	Hofrath.
Kawara, Saburo, 64 Higashikata Machi, Nagoya, Japan.	Chemist, Morimura Brothers.
Ludlow, Stephen H., Durham, Ontario, Canada.	Chemist, National Portland Cement Company.
Olsen, Norman, Palermo, Sicily.	Asst. Mgr.,The Manifattura Ceramica Florio.
Page, Edwin Percival, Stourbridge, England.	Draughtsman, E. J. & J. Pearson's, Ltd.
Rauter, Dr. Gustav, Charlottenberg 4, Berlin.	Engineering Chemist.
Rix, Wilton Parker, 8 Kinglake Road, Egremont, Cheshire, England.	Consulting Chemist.
Rum Bellow, H. A., Leeds, England.	Chief Research Chemist, Leeds Fire Clay Company.
Sweet, George A., F. G. S., Brunswick, Victoria, Australia.	"The Close," Wilson St.
Thomas, Charles William, Pedmore, near Stourbridge, England.	Director, E. J. & J. Pearson, Ltd.

RESIDENT ASSOCIATE MEMBERS.

Acheson, Edward Goodrich, Niagara Falls, N. Y.	Pres. Acheson Company.
Aldrich, John C. Pittsburg, Pa.	Star Encaustic Tile Company.
Ashley, Harrison Everett, 189 George St., E. Liverpool, O.	Homer Laughlin China Company.
Barnes ,Arthur E. Norristown, Pa.	Gen'l Mgr., Reconstructed Granite Company.
Bauslog, Samuel Allen, Peru, Indiana.	Asst. Supt., Peru Electrical Manufacturing Company.
Bloomfield, Charles A., P. O. Box 413. Metuchen, N. J.	Dealer in Clays.
Booth, Thomas C., Perth Amboy, N. J.	Perth Amboy Terra Cotta Company.
Bowman, Robert K., Trenton, N. J.	Treas., Trenton Fire Clay & Porcelain Company.
Bowman, William, J. J., C. E., Trenton, N. J.	Trenton Fire Clay & Porcelain Company.
Britton, Dr. Charles P., Trenton, N. J.	Star Porcelain Works.
Burr, Francis T., 150 Nassau St., New York, N. Y.	Mgr., Richmond Kaolin Company.
Campbell, Augustine R, Tottenville, S. I., N. Y.	Atlantic Terra Cotta Company.
Clark, Thomas W., Charlestown, W. Va.	809 Donally St.
Clarke, William R, 156 Fifth Ave., New York City.	Pres., Celadon Roofing Tile Company.
Colgan, Frank J., Grassy Point, N. Y.	Salesman for A. M. & W. H. Wiles, Manf. Clayworking Machinery.
Conkling, Ira L, Philadelphia, Pa.	Pres., Conkling-Armstrong Terra Cotta Company.
Defebaugh, Edgar H., Louisville, Ky.	Editor and Publisher, "Rock Products."
Diedrick, William H., Salineville, Ohio.	Pres. and Gen. Mgr., The Dresden China Company.
Ellerbeck, Dr. Wm. Leon, Salt Lake City, Utah.	Doctor Dental Surgery.
Eskesen, Bennet K., Matawan, N. J.	Supt., New Jersey Mosaic Tile Company.
Eskesen, Thoge R., Matawan, N. J.	The New Jersey Architectural Terra Cotta Company.
Ettla, George S., Niagara Falls, N. Y.	Pres., United Barium Company.

Evatt, Frank G., Paddock Bldg., Boston, Mass.	Dealer in Building Materials.
Ferguson, Silas M., Wellsville, Ohio.	United States Pottery Company.
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Frank, S. Ettinger, 6 Bridge St., New York.	President, The Schwarz System Brick Company.
Franzheim, Charles, Wheeling, W. Va.	Wheeling Potteries Company.
Frerichs, William D., Tottenville, S. I., N. Y.	Atlantic Terra Cotta Company.
Gates, Ellis Day, Terra Cotta, Ill.	American Terra Cotta and Ceramic Company.
Gates, William P., Terra Cotta, Ill.	American Terra Cotta and Ceramic Company.
Golding, Charles E., Trenton, N. J.	Mgr., William Golding Sons Co.
Gorsline, William Henry, 334 East Ave., Rochester, N. Y.	Treas. and Mgr., Rochester Sewer Pipe Company.
Grady, Robert F., St. Louis, Mo.	Mgr., St. Louis Terra Cotta Company.
Gray, Thomas, East Boston, Mass.	New England Pottery Company.
Grueby, William H., Boston, Mass.	Pres. and Gen'l Mgr., Grueby Faience Company.
Guastavino, Rafael, Jr., 49 E. 19th St., New York.	Supt., The R. Guastavino Company.
Hamilton, Percy C., 326 Fourth Ave., Pittsburg, Pa.	Manufacturer Sewer Pipe.
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Hardy, Isaac Ernest, Momence, Ill.	Supt., Tiffany Enameled Brick Company.
Hasburg, John W., 588 Fullerton Ave., Chicago, Ill.	Dealer in Ceramic Materials
Hasslacher, Jacob, 100 William St., New York, N. Y.	Roessler and Hasslacher Chemical Company.
Haugh, B. O., Anderson, Ind.	Manager, National Tile Company. Columbia Plant.
Haugh, Harry, Anderson, Ind.	Supt., National Tile Company, Columbia Plant.
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Koch, Julius J., Shawnee, Ohio.	Supt., Iron Clay Brick Co.
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Kwiatkowski, Louis F., 114 Liberty St., New York.	Civil and Mining Engineer, with H. Huennekes & Co.
Landers, William Franklin, Indianapolis, Ind.	Supt., U. S. Encaustic Tile Works.
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Loundes, William Bladen, Mt. Savage, Md.	Supt., Mt. Savage Fire Brick Company.
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Maddock, Thomas, Trenton, N. J.	John Maddock & Sons.
Maddock, John, Trenton, N. J.	John Maddock & Sons.
Mandle, I., St. Louis, Mo.	Miner and Shipper of Pottery Clay. 3943 Pine St.
McBean, Athole, San Francisco, Cal.	Secy. and Treas., Gladding, McBean & Company.
Meakin, Robert J., E. Liverpool, Ohio.	Mgr., Hall China Company.
Middleton, Jefferson, Washington, D. C.	Statistician, United States Geological Survey.
Minton, Leroy Hines, Mineral City, Ohio.	With C. Edwards Holden.
Morris, W. C., St. Louis, Mo.	Vice-Pres. and Gen. Mgr., Christy Fire Clay Company.
Moses, James, Trenton, N. J.	Mercer Pottery Company.
Ogan, Mark, St. Louis, Mo.	St. Louis Terra Cotta Company. 5801 Manchester Ave.

Ogden, Ellsworth, 106 Price St., Columbus, Ohio.	Student, Ohio State University, Ceramic Department.
Page, Logan Waller, Washington, D. C.	Chief, Road Material Laboratory, U. S. Dept. Agriculture.
Parker, Lemon, St. Louis, Mo.	Parker-Russell Mining and Manufacturing Company
Parmelee, Cullen W., B. Sc., New Brunswick, N. J.	Director, Dept. Ceramics, Rutger's College.
Plant, Alfred, Keyport, N. J.	Eagle Tile Company.
Pope, Charles A., Trenton, N. J.	Trenton Fire Brick Company.
Post, Malcolm P., St. Louis, Mo.	Foreman, Blackmer & Post, Sewer Pipe Company.
Powell, William H., New York, N. Y.	Excelsior Terra Cotta Company.
Preston, Francis C, Cleveland, O.	Sales Agent, Dover Fire Brick Co. 509 Cuyahoga Bldg.
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Ramsey, Andrew, Mt. Savage, Maryland.	Mt. Savage Enameled Brick Co.
Randall, Theodore A., Indianapolis, Ind.	Editor "Clay-worker."
Rea, William J., Buffalo, N. Y.	Supt., Buffalo Pottery Company.
Rhodes, William Albert, E. Liverpool, Ohio.	Vice-Pres., Colonial Company.
Robineau, Samuel E., Syracuse, N. Y.	Editor "Keramic Studio."
Robinson, Edward Wanton, Hartford, Conn.	Gen. Mgr., Hartford Faience Co.
Roessler, Franz, 100 William St., New York.	Vice-Pres. and Supt., Roessler & Hasslacher.
Rowe, John, Zanesville, Ohio.	Asst. Supt., American Encaustic Tiling Company
Royse, Daniel, 45 Plymouth Place, Chicago, Ill.	Man. Editor, Windsor & Kenfield Publishing Company.
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Sant, John, E. Liverpool, Ohio.	Clay Salesman, Miner and Broker.
Schoedel, J. A. W., St. Louis, Mo.	Supt., Christy Fire Clay Co.
Simpkins, Ralph, St. Louis, Mo.	Mgr., Union Pressed Brick Works.
Singer, Lewis P., Lincoln, Cal.	Chemist, Gladding, McBean & Co.
Skeele, H. B., Chicago, Ill.	Ludowici Roofing Tile Company.

Smith, Amedee M., Portland, Oregon,	Western Clay Manufacturing Co.
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Stamm, John, East Liverpool, Ohio.	General Manager National China Company.
Stanbery, George A., Zanesville, Ohio.	American Encaustic Tile Company, Ltd.
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Taylor, William Watts, Cincinnati, Ohio.	President Rookwood Pottery Co.
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Thrall, Charles U., Tottenville, S. E., N. Y.	Supt., Atlantic Terra Cotta Co.
Townsend, Everett, Morrisville, Pa.	National Tile Company.
Trommer, Carl E, 100 William St., New York.	Roessler and Hasslacher Chemical Company.
Tweedy, Edward P., West Cornwall, Conn.	Clay Miner.
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Walker, John A, Jersey City, N. J.	Joseph Dixon Crucible Company.
Weelans, Charles, Trenton, N. J.	Supt., Monument Pottery Co.
Welch, John H., St. Louis, Mo.	The Mound City Roofing Tile Co. 3235 Morganford Road.
Whitehead, C. Louis, Trenton, N. J.	Providential Tile Works.
Williams, Ira A., B. S., Ames, Iowa.	Geological Department, Iowa State College.
Wolf, George, Marshalltown, Iowa.	Supt., Marshalltown Pottery Co.
Worcester, Wolsey Garnet, Groveport, Ohio.	Gen. Mgr., Central Ohio Roofing Tile and Brick Co.
Yates, Alfred, Johnsonburg, Pa.	Johnsonburg Vitrified Brick Co.
Young, George F., Zanesville, Ohio.	Mgr., Roseville Pottery Co.
Youngren, Peter Lewis, 261 15th St., Milwaukee, Wis.	Kiln Builder and Burner.

RULES.

OBJECTS.

The objects of the Amercan Ceramic Society are to promote the arts and sciences connected with Ceramics by means of meetings for social intercourse, for the reading and discussion of professional papers, and for the publication of professional literature.

MEMBERSHIP.

The Society shall consist of Honorary Members, Members and Associates.

Honorary Members must be persons of acknowledged professional eminence, and shall not exceed five in number.

Members shall be persons competent to fill responsible positions in Ceramics and have suitable qualifications.

Associates shall include persons interested in Ceramics and the allied arts.

Honorary Members shall be proposed by at least five Members, approved by the Council, and receive at least 90 per cent. of the votes cast by letter ballot at the annual meeting.

Members and Associates shall be proposed by at least three Members or Associates, approved by the Council, and receive at least 75 per cent. of the votes cast by letter ballot. A candidate for admision must make application on a form prepared by the Council which shall contain a written statement of his age, professional experience, and that he will if elected, conform to the laws, rules, and requirements of the Society.

All Honorary Members, Members and Associates shall be equally entitled to the privileges of membership, except that only Members shall be entitled to hold office and to vote. Applicants for a change in grade of membership shall conform to the requirements of a new applicant.

Any person can be stricken from the membership of the Society on the request of five or more Members, on the recommendation of a majority of the Council, if he fails to resign on the advice of the Council. Such person, however, shall first be notified of the charges against him, and be given a reasonable time to appear before the Council, or present written defense, before final action is taken by the Council

DUES

Honorary Members shall be exempt from all dues.

The initiation fee of Members shall be ten dollars, and of Associates five dollars, which if not paid within six months after election, will render the election void.

The annual dues for Members will be fixed by the Council, but shall not exceed five dollars per year.

The annual dues for Associates will be fixed by the Council, but shall not exceed four dollars per year.

Any Member or Associate in arrears for over one year may be suspended from membership by the Council until such arrears are paid.

OFFICERS.

The affairs of the Society shall be managed by a Council, consisting of a President, Vice-President, Secretary, Treasurer, and three Managers, who shall be elected from the members at the annual meeting, and hold office until the adjournment of the meeting at which their successors are elected.

The President, Vice-President, Secretary and Treasurer shall be elected for one year, and the Managers for three years and no President, Vice-President, or Manager shall eligible for immediate re-election to the same office.

The duties of all officers shall be such as usually appertain to their offices, or may be delegated to them by the Council or the Society; and the Council may at its discretion require bonds to be furnished by the Treasurer.

Vacancies in any office shall be filled by appointment by the Council, but the new incumbent shall not thereby be rendered ineligible to re-election at the next annual meeting to the same office. On the failure of any officers to execute his duties within a reasonable time, the Council after duly warning such officer may declare the office vacant, and appoint a new incumbent

A majority of the Council shall constitute a quorum; but the Council shall be permitted to carry on such business as it may desire by letter.

ELECTIONS.

At the annual meeting, a nominating committee of five Members, not officers of the Society, shall be appointed, and this committee shall send the names of nominees to the Secretary at least 60 days before the annual meeting, who shall immediately forward the same to the Members. Any other five members may also present the names of any candidates to the Secretary, provided it is done at least 30 days before the annual meeting. The names of all candidates, provided their assent has been obtained, shall be placed on the ballot without distinction as to nomination by the regular or an independent com-

mittee, which shall be mailed to every member, not in arrears, at least 20 days before the annual meeting. The ballot shall be inclosed in an inner blank envelope, and the outer envelope shall be endorsed by the voter, and mailed to the Secretary for collection. The blank envelopes shall be opened by three Scrutineers appointed by the Chair at the annual meeting, who will report the result of the election. A plurality of the votes cast shall elect.

MEETINGS.

The annual meetings shall take place at such time and place as the Council may decide, at which time reports shall be made by the Council, Treasurer, and Scrutineers of election, and the accounts of the Treasurer, audited by a committee of three appointed by the Chair.

Other meetings may be held at such times and places during the year as the Council may decide, but at least 20 days' notice shall be given of such meetings.

Seven members shall constitute a quorum at any regular meeting, and a majority shall rule, except when otherwise specified.

The order of business at the annual meeting shall be:—

1. Reading of Minutes of last meeting.
2. Reports of the Council and Treasurer of the Society.
3. Announcement of Election of Members.
4. Announcement of the Election of Officers.
5. Appointment of Nominating Committee.
6. Old Business.
7. New Business.
8. Reading of Papers.

PUBLICATIONS.

The Council shall act as a Publication Committee, and decide as to what to publish. The publications of the Society shall be sent to all Members and Associates not in arrears. The Secretary will furnish each author with reprints of his papers at cost price, provided due notice is given that reprints are desired.

The Society is not, as a body, responsible for the statements or opinions expressed in its publications.

PARLIAMENTARY STANDARD.

Roberts' "Rules of Order" shall be the parliamentary standard on all points not covered by these rules.

AMENDMENTS.

These rules may be amended at any regular meeting by a two-thirds vote of a letter ballot at the subsequent annual meeting, provided a written notice of such proposed change is sent to each Member at least 30 days before said annual meeting. Said proposed amendments shall be printed on the ballot or officers and counted by the same Scrutineers.

PUBLICATIONS.

The publications of the Society are as follows:

Description of Volume.	Price to Members.	Price to Others.
Vol. I. Transactions for 1899, 110 pages, bound in paper,	$0.50	$4.00
Vol. II. Transactions for 1900, 278 pages, bound in paper,	3.00	4.00
Vol. III. Transactions for 1901, 230 pages, bound in paper,	3.00	4.00
Vol. IV. Transactions for 1902, 300 pages, bound in paper,	1.50	4.00
Vol. V. Transactions for 1903, 420 pages, bound in paper,	2.00	4.00
Vol. VI. Transactions for 1904, 287 pages, bound in paper,	1.50	4.00
Manual of Ceramic Calculation (contained in Vol. II as a part thereof,) 86 pages, bound in paper,	1.00	1.00
The Collected Writings of Dr. Hermann August Seger, Volume I. Contains (A) Treatises of a general scientific nature, (B) Essays relating to Brick and Terra Cotta, Earthenware and Stoneware, and Refractory Wares. Pages, 552. Bound cloth,	7.50	7.50
The Collected Writings of Dr. Hermann August Seger, Volume II. Contains (B) Essays on Whitewares and Porcelain. (C) Travels, Letters and Polemics. (D) Uncompleted works, and extracts from the archives of the Royal Porcelain Factory. Pages, 605. Bound in cloth,	7.50	7.50
Cost of full set, not including manual.....	26.50	39.00

At the last meeting, the council fixed a sliding scale of prices to apply to the sale of volumes of the Transactions, when the number unsold falls below 200 copies. As the copies become scarcer, prices will be increased to both members and others. The supply of two of the volumes has already fallen below 200 copies, and is diminishing steadily, and one other will probably pass below this mark during the

coming year. Members and Associates who do not yet own full sets are advised to procure them at once.

At the same meeting the following resolution was adopted:

Resolved, that the custom by which members and associates may obtain copies of the Transactions at reduced or so-called "members rates," is intended only to enable each person to obtain one complete file of the transactions.

The necessity of this resolution arose from the expressed desire of a member to buy a copy of the transactions, with the intent to sell it to a friend for whom he wished to save the additional price charged to non-members. In accordance with the spirit of this resolution, the Treasurer will not supply more than one copy of a volume to a member at reduced rate, except when loss or destruction of a volume gives good cause for so doing.

At the same meeting, it was ordered that the Secretary should insure the copies of the Transactions still in his care, which has been done in the sum of $2,000.

Every member or associate receives one copy of the Transactions free for each year for which he pays dues. He is entitled to purchase copies for the years antedating his connection with the Society at the costs indicated in the first column. All others can obtain copies at the prices listed in the second column by sending order, accompanied with check, to

STANLEY G. BURT,
Care of Rookwood Pottery Co.,
Cincinnati, Ohio.

LIST OF MEMBERS AND ASSOCIATES PRESENT AT SIXTH ANNUAL MEETING.

Acheson, Edward G., Niagara Falls, N. Y.
Barringer, Lawrence E., Schenectady, N. Y.
Binns, Prof. Chas. F., Alfred, N. Y.
Bleininger, Albert V., Columbus, Ohio.
Bloomfield, Charles H., Matawan, N. J.
Bowman, Robert K., Trenton, N. J.
Bowman, William J. J., Trenton, N. J.
Burr, Francis T., New York, N. Y.
Burt, Stanley G., Cincinnati, Ohio.
Campbell, Alexander R., Tottenville, N. Y.
Clark, Thomas W., Charleston, W. Va.
Cushman, Allerton S., Washington, D. C.
Eskesen, Thoge R., Matawan, N. J.
Frerichs, William D., Tottenville, N. Y.
Ettinger, Frank S., New York, N. Y.
Gates, William D., Chicago, Ills.
Geijsbeek, Samuel, St. Louis, Mo.
Hasburg, John W., Chicago, Ills.
Higgins, Aldus C., Worcester, Mass.
Hottinger, Adolph F., Chicago, Ills.
Hull, Walter A., Shawmut, Pa.
Jeppson, George N., Worcester, Mass.
Koch, Charles Frederick, Covington Ky.
Landers, William F., Indianapolis, Ind.
Mandle, I., St. Louis, Mo.
Ogan, Mark, St. Louis, Mo.
Ogden, Ellsworth, Columbus, Ohio.
Orton, Edward, Jr., Columbus, Ohio.
Parker, Lemon, St. Louis, Mo.
Parmelee, Cullen W., New Brunswick, N. J.
Post, Malcolm P., St. Louis, Mo.
Purington, Dilwyn V., Chicago, Ills.
Robinson, Edward W., Hartford, Conn.
Sant, John, East Liverpool, Ohio.
Stull, Ray T., Elkland, Pa.
Taylor, W. W., Cincinnati, Ohio.
Volz., William J., St. Louis, Mo.
Walker, Francis W., New Brighton, Pa.
Watts, Arthur S, Victor, N. Y.
Weelans, Charles, Trenton, N. J.
Wheeler, H. A., St. Louis, Mo.
Worcester, W. W., Columbus, Ohio.
Young, George, Zanesville, Ohio.

PREFACE

This volume contains the records of another successful meeting and another year of profitable work. The Cincinnati meeting measured up to any preceding meeting in every respect, except possibly the number of papers, which were somewhat fewer, though more than could be read in the time available. The attendance was excellent, there being more than fifty present, though a number of these were not members of the society and did not become so at that time.

This volume contains, besides papers from our regular members, contributions of more than ordinary value from Mr. E. G. Acheson and A. S. Cushman, neither of whom had up to that time been identified with the Society's work, but who turned to it as the best body before whom to present their researches in America. This recognition is naturally gratifying to the members as evidence that they are making headway towards the goal which they have set themselves to reach.

The volume is also improved by the addition of several theses prepared by students in ceramic schools or other colleges. There were a number of other documents of this character which were not included, chiefly for lack of time to abstract them and prepare them for printing.

During this year, the Society has entered a new field of work, through its Committee on Ceramic Literature, which under the chairmanship of Prof. Charles F. Binns, has made a good beginning on the task of presenting a digest or review of the notable additions to ceramic literature for the year. This review is intended to cover the work of the German, French and English technical press, besides that of other ceramic societies.

The continued growth in membership is worthy of remark. Notwithstanding the natural losses by death and withdrawal, the list has shown a healthy and vigorous increase each year, and that of the current year is greater than that of any preceding. The following table shows the facts as to the Society's growth.

YEAR.	1899	1900	1901	1902	1903	1904
Honorary Members	1	1	1	1	1	1
Foreign Members	..	..	1	1	1	1
Resident Members	21	23	23	26	25	29
Foreign Associates	..	1	3	7	7	16
Resident Associates	6	32	51	67	92	119
Totals	28	57	79	102	126	166

The foreign membership is steadily increasing. For the first time their names are listed separately; though this measure was prompted

by convenience, it calls attention to the fact not sufficiently appreciated by ourselves, that our foreign list has become quite a factor in our membership, and that our literature is steadily making its way into every civilized country in the world.

The Society ordered, at the suggestion of Professor Wheeler, that a set of its publications be sent to the World's Fair, at St. Louis, for exhibit in the Clay Industries space. I am gratified to report that the Society was awarded a silver medal for this exhibit, and this without any effort upon the part of its members or officers. The jury passing upon technical journals was separate from that examining clay exhibits, and their award is all the more gratifying in view of its unexpectedness.

The Secretary desires to say that the lateness of the issue of this volume is due to a combination of causes, which have not only delayed its appearance, but have actually restricted the size and value of the volume below what it could have been made. There has been ceramic literature in sight which could have been secured for this volume had it been possible to give it the time and attention required. Had this situation not been temporary, it would have been necessary to ask for an Editing Committee to take charge of the work; it is likely that the increasing size and importance of our publications will lead to this in time in any case, but for the present the system now in force has the merit of simplicity and economy which are not likely to be surpassed until a paid editor is possible. This has been suggested in connection with the founding of a monthly journal, but so far has led to no consideration of the plan.

New announcements concerning publications appear in a separate page.

EDWARD ORTON, JR.,
Secretary.

Columbus, O., Dec. 10th, 1904.

OPENING ADDRESS

BY

PRESIDENT FRANCIS W. WALKER, Beaver Falls, Pa.

There are times in everyone's life when words fail to express adequately one's feelings.

This is such a time in my life; I am unable to convey my full appreciation of the honor conferred upon me, an honor all the sweeter and more dearly prized because offered by my friends and associates. I can only thank you, and ask your indulgence as well as assistance in performing the duties of the office.

Last year as vice president, at the Boston meeting, I had the extreme pleasure of introducing our now retiring President, Mr. Stover. Soon after his return home from that meeting, he was taken seriously ill, which illness has confined him to his home most of the year and I am sorry to say prevents him from being with us today. I know all of you will join with me in wishing him a rapid and complete recovery.

This is the opening session of the Sixth Annual meeting and in this connection I wish to call your attention to a peculiar difference between our society and most other organizations, viz.: Our volume of annual proceedings date from the beginning of each year. We occupy the somewhat unique position of having published our first volume from papers read and discussions held at the organization meeting.

This meeting should prove a most valuable one from a practical standpoint, it being the first opportunity that many of us have had of visiting the world renowned Rookwood Pottery. It also marks the beginning of a new procedure adopted at our last meeting, of publishing papers in advance when presented in time, in order to permit a more comprehensive discussion.

The growth of our society has been most satisfactory. The increase in active membership, while small in number, has been of very great worth; the large increase, however, has been in associate members, the list having increased from thirty-three the second year, to fifty-five the third, seventy-four the forth and ninty-nine the fifth year. It is from our associate members that the active list must be increased and every encouragement will be

given to bring into the active list every associate who is willing to advance the good of the society with his technical skill. We have a number of associates who have shown their competency in ceramics; we earnestly invite them to show also their willingness to assist in the advancement of the ceramic industry that we have undertaken through the operations of this society. Some of the most valuable papers read before our previous meetings have been from associate members, and the indications are that this meeting will not be an exception.

I take great pride and pleasure also in calling your attention to the fact that we have had some valuable papers contributed from outside membership, as well as from our foreign members from across the great waters, who have shown their desire to be heard through the channels of our society. This should be conclusive evidence of the broad field of our influence. It is no small compliment that those who have knowledge to impart feel the desire to give it out to the world through the American Ceramic Society. This intercourse and exchange of knowledge with the older and more experienced pottery countries should be encouraged. They can give us many valuable and practical suggestions, while we hope they may receive from us some information which our well known freedom from conventionality may have enabled us to acquire better than the more conservative practice of the Old World.

The literature which has emanated from our society so far redounds greatly to its credit, and as time rolls on, it will be an encouragement to others to take up the field of research, which is only in its infancy, and add their share to the sum of human knowledge.

Perhaps the monument that will stand to our greatest credit with the English speaking world is the translation and publication of that wonderful Primer on Ceramics, "The Collected Writings of Dr. Herman Seger." This work was undertaken at the organization meeting of our society, and after five years of laborious work on the part of the editor, the committee in charge, and some of the members, they were able before the close of the fifth year to put within the reach of all English speaking people this invaluable document. Too much praise cannot be given to those who performed the tedious labor connected with this task.

When you consider the annual income of the society at the time of its inception, and its decision to translate and publish in English this great work with only $115.00 in sight, then and only then can you fully realize the enthusiasm of the small "band" of workers who had just associated themselves together for the common weal and advancement of the clay working world. If our society should do no more, it has already accomplished a great work.

Has that enthusiasm, if you wish to call it such, been on the wane since the inception of our society? In answer, I will ask you to look over carefully the papers appearing in the Transactions. Compare the later papers with the earlier ones, and without placing one atom of criticism upon the first products of the society, I feel sure you will all agree with me that the development of thought as well as technique shows a wonderful advancement in knowledge and resource. Professor Wheeler in his retiring address at Detroit, encouraged us to look forward to the technical advancement of the industry, citing the wonderful place the steel industry had assumed through the technical skill of their chemists, and pointing out the barriers that secretiveness had thrown around the manipulations of its manufacture, at the time the chemists was brought into the field as a factor. Was it an easy task for these first hard-plodding technicists? Those of you who have read the "History of the Carnegie Steel Company" will recall the difficulties of that enlightened concern when their expert chemists come in contact with the obstruction of the "practical superintendent." In this respect the iron industry is not an exception.

An examination of the history of the clay industries will still show you "secrecy" and "ignorance" working hand in hand. Many of the so-called "secrets" are really most valuable knowledge, but the owner in many cases does not know that they are merely good illustrations of the simple technical laws. It is the law that is valuable, not the isolated example of its action. As greater knowledge is placed within the reach of such persons, they will soon see, as they did in the steel industry, that the information to be obtained from the technical student will more than repay them for the "giving up" of some of their practical knowledge.

I think I am safe in saying that Professor Wheeler's pre-

cursory remarks have already shown signs of working out; many of our practical potters are beginning to realize that the information to be had through this society is of the highest value. This accounts in many instances, for the additions to our associate membership list. As time rolls on, we hope that the "practical men" among our associate members will begin to feel that they must assist in the advancement of knowledge, and that we will find them working on the difficult problems of the ceramic industry in connection with the technicist, for the benefit of our meetings.

Through our association with, and meeting at the same time and place as the National Brick Manufacturers Association, we have succeeded in getting a large membership from that industry. We have convinced the brickmaker that the influence of this society is for the good of all manufacturers of clay. Is it not possible to have this same influence thrown around the "potter," so as to enlarge our membership among the manufacturers of the more delicate and artistic lines of ware? If this can be accomplished, our literature will become replete with many valuable contributions as well as our meetings strengthened by the presence and influence of many newcomers. They will have the pleasure of assisting in unraveling some of the very problems that they are now unable to attack successfully.

A few days ago, I noticed the question asked, "How would you spend $1,000,000 for science?" Replies from a number of eminent scientists: "Hygienic living," "Exploration," "Ornithology," "Aeronautics," "Philanthropy," "Art," etc., all had their advocates. The reply that struck me most forcibly was along the line of practical science in agriculture by Hon. James Wilson, Secretary of Agriculture, wherein he pointed out what science had done and was doing for the benefit of mankind on the farm. In discusing what the scientific treatment of the soil will do to increase the products of crops he stated that the government was spending about six million dollars annually for the advancement of science along these lines, and said further, "I would like to spend a million more dollars in teaching the people about the lands they walk on and from which they draw their sustenance." In reading this statement I could not help but draw a comparison between the encouragement received by the clay industries of

France and Germany and that given by our governments. Should not our government do for the clay worker at least a part of what it is doing for the advancement of science in other lines?

The Geological Survey Department could do most valuable work for the clay industries of the country, giving the complete analysis and physical tests of the deposits in all sections; such reports would add greatly to our literature and be invaluable to the clay worker. Is it not worth the effort to try to have this done?

Again thanking you for the honor conferred upon me, we will proceed to the business before us.

DISCUSSION.

Professor Edward Orton, Jr.: It seems to me the President has made an exceedingly valuable suggestion this morning, in pointing out what might be profitably done by the Government towards the development of the ceramic industry. It is something I have thought of from time to time in the past, but never in just the light in which our President has brought it forward.

Of course, we must recognize that the government is already spending more or less money in the development of our work, and is doing it in several different ways. You will notice on the program for this meeting a paper by Dr. A. S. Cushman of the Road Material Laboratory in the Bureau of Agriculture. This Bureau is taking up the matter of good roads, and that involves the use of clays, and clay products most extensively. Both Mr. Page and Dr. Cushman of that department have been pursuing a very interesting series of researches along this line and their bulletins are full of valuable information.

In another way, the Government is helping us, by supporting tthe State universities. In two of these institutions we now have departments directed especially to our line of work, and the chances are that this work will in a short time be extended to other schools. In Iowa, they had gone to the length of announcing the opening of a ceramic department several years ago, but owing to a fire immediately afterward, which crippled the resources of the institution seriously, no very tangible results have come of it, but I look forward confidently to the time when we will have Iowa in our work.

Besides the schools which maintain formal ceramic depart-

ments, nearly all of them give good training in the Chemistry, Physics and Mathematics which are fundamental in this and all other engineering and technical industries, and many more give many other courses coming still closer to our field of operations, as metallurgy, economic geology, use of fuel, thermodynamics and the like.

You say that is state work; but after all, these state schools owe their foundation to the government act of 1862 and owe their continued support to a government act of 1890. So they not only receive their original start from the government, but a part of their present support comes directly from government money, and to that extent the government is helping us now. But its influence helped us most, when it placed in the hands of the legislatures of the different states opportunity and incentive to still further broaden and increase this work of industrial education as they may see fit.

The direct appeal to the government to take up more specifically work for the clay industries, probably through the United States Geological Survey, seems to me a good suggestion. They have done more or less work in examination of the clays of different states; a large Bulletin has recently appeared from the pen of Dr. Ries. I think there is no doubt that if the matter is properly presented to the Director of the Geological Survey it will be productive of results. In fact, one of the corps indicated to me several years ago that a monograph on a certain subject could easily be had if it was gone about in a proper way. It seems to me that the efforts of this society were directed toward selecting some one topic upon which it is desired to have an investigation made, that an official request to the Department to take it up would very posibly be granted.

The idea of establishing a pottery, subsidized by the government, and specially directed to the production of the most ornate and artistic articles as is done in the French factory at Sevres, or of a Government-supported testing station and experimental bureau, like the Versuchs-Anstalt at Charlottenburg, Berlin, in Germany, has never been broached in this country so far as I am aware.

Whether the idea would meet favor among statesmen in this country is doubtful, and I should not be surprised if some murmurs were heard from the ceramic industries themselves on the subject of undue competition and unnecessary expenditure of public funds.

Be this as it may, President Walker's suggestion has served to call our attention to a subject of fruitful interest.

EGYPTIANIZED CLAY.

BY

EDWARD G. ACHESON, Niagara Falls, N. Y.

Having worked out the problems involved in the manufacture of graphite from coal and other carbonaceous materials, I undertook in the summer of 1901 the introduction of this artificially-made graphite into the crucible trade. The first step being the production of a crucible, I set to work on the making of a satisfactory one of my graphite, using as a binding material domestic clays employed in neighboring factories. Many difficulties were encountered and much confusion resulted in the effort to properly place the blame, whether on the graphite or clay. I soon learned that the manufacturers of crucibles in the United States invariably used clays imported from Europe, and more particularly from Germany. I obtained samples of the German clays and found them much superior to the domestic ones, in the matter of plasticity and tensile strength. A chemical analysis failed to disclose the cause of the differences. The question involved was of a kind that interested me much, and I read everything at hand pertaining to the subject, including a great deal about residual or primary clays; sedimentary or secondary clays; kaolins and ball clays; bacteria and organic matter; ageing and plasticity and much more that was interesting and otherwise, and in the main confusing and wholly wanting in an adequate explanation of why in nature we find two clays almost identical in chemical composition while decidedly different in physical properties.

I was perhaps fortunate in being a stranger to the art of clay working, unbiased in my opinions, accustomed through my experiences with the discovery and development of carborundum and artificial graphite, to think and act without regard to the recorded opinions of others—a free lance. Under these influences, or rather free from influences, I concluded to endeavor to determine the cause of these varying conditions. We had here to do with one of nature's methods of preparing her products for the use of man. We are quite used to her method of modification by chemical alteration, but this was a case of a definite chemical compound appearing under varying physical characteristics—a condition of metamorphism, presenting a study some-

what analogous to the transformation of anthracite coal into graphite, a problem I had but recently solved. I found it generally stated that residual clays were usually of low plasticity, while sedimentary clays were more or less highly plastic. Here was the starting point. Plasticity seemed to be developed by or during the act of transformation from the point of formation to the final resting place. I did not believe that there was anything in the simple suspension in water that would produce the effect noted, and therefore looked to the possible foreign matter carried by the water for the primary cause. It seemed to me the most likely agents were the organic substances washed into the running waters from the forests. With this idea in view, I made a few experiments with those substances I thought likely to be found in the washings of vegetation. The first experiment was to suspend kaolin in a solution of acetic acid, allowing it to remain some hours, watching meanwhile for any change that might occur. No change was detected.

The second experiment was to treat kaolin in a similar manner with carbolic acid, with the like negative results. The third experiment was to treat kaolin with creosote, with the same negative results. The fourth experiment was to treat the kaolin with solution of gallo-tannic acid, and I at once noticed that the presence of the tannin reduced the amount of water necessary to produce the desired fluidity, and on further examination the tensile strength and plasticity were found to be increased. Systematic experiments were now started, and I cannot give the results of the next few months better than by quoting from the laboratory notes as kept by my then assistant, Mr. F. A. J. Fitzgerald:

Aug. 24: 40 kilograms of kaolin were weighed out into a tub and to this were added 39 kilograms of water, in which was dissolved 194 grams of gallo-tannic acid. As thorough a mixture as possible was made, but all the lumps could not be broken up. The mixture will be allowed to stand several days in the hope that a more complete disintegration of the clay will take place.

Aug. 26: To the mixture in the tub was added 1 kilogram of water, in which was dissolved six grams of gallo-tannic acid. This makes the total mixture:

Kaolin	40 kilograms
Water	40 kilograms
Catechu	0.2 kilograms

This makes an addition of 0.5 per cent. gallo-tannic acid to the clay. The lumps originally noticed in the mixture in the tub are gradually disappearing.

A mixture of 210 grams of kaolin and 210 grams of water was made up and compared with the mixture in the tub. Although the proportions of water and clay are the same, the mixture made up without the gallo-tannic acid is very much stiffer than that from the tub.

Aug. 30: Mixture in the tub has been well stirred every day and appears to become thinner on standing.

A specimen of the clay under treatment in the tub was taken out by dipping a dish to the bottom and then raising out of the tub. Another sample was taken out by dipping only three inches below the surface of the mixture. Both samples were dried on the water bath, and were found to have a different color when dried. Both samples give strong blue color when tested with solution of Ferric Chloride.

Ten grams of the dried specimen from the bottom of the tub was moistened with water, also ten grams of ordinary kaolin, which had not been treated with the tannin, was moistened with the same amount of water. The kaolin which had been treated with the tannic acid became quite liquid, while the ordinary kaolin was viscous.

To find effect of very small amounts of tannin a solution containing 0.1 per cent. was made up. Two specimens of kaolin, of 10 grams each, were weighed out. To one was added 10 ccs. of water, to the other 10 ccs. of the 0.1 per cent. tannin solution. The latter is distinctly more fluid than the former.

Aug. 31: A specimen of clay taken from the bottom of the tub (Aug. 30) was taken for filtration today. The centrifugal machine was used, but it was impossible to obtain a clear solution in that way. The mixture was then thrown on a filter and every precaution taken to obtain a clear filtrate; but it was found impossible to obtain a clear liquid. The material on the filter was washed and the clay frequently tested for tannic acid. After prolonged washing the reaction with ferric chloride appeared to be just as strong as at the first. This suggested the notion that some compound insoluble in water was formed by the tannic acid and clay. Some of the clear supernatant liquid in the tub was therefore tested with ferric chloride, and have no reaction therewith. The ferric chloride reaction is a very delicate one, as it was found that it gave a very deep blue color with a tannic acid solution of 1 in 1,000.

I now began to wonder at the effect being unknown, one that might have so much value to an industry of such colossal dimensions and great antiquity as clay-working. Moreover, it was amazing that it should not be known in view of the tremendous amount of experimental work done on the art, as instanced by the reputed 30,000 experiments of the German chemist Pott,

on the manufacture of porcelain. I made an effort to find in the history of clay-working some record of the addition of vegetable or organic matter to clay. Only one instance could I find, that of the Egyptians as recorded in the fifth chapter of Exodus. The accepted theory of using the straw fibre as a binding agent for the clay never had appealed to me, and it now seemed likely those ancient people were familiar with the effect I had discovered. I procured some oat straw, boiled it in water, decanted the resultant reddish-brown liquid and mixed it with clay. The result was like that produced with gallo-tannic acid, and equal to the best I had obtained. This explained why the straw was used, and why the Children of Israel were successful in substituting stubble for straw, a course that would hardly be possible were the fibre of the straw depended upon as a bond for the clay, but quite feasible where the extract of the plant was used.

I would here call attention to the fact that an experiment with a certain clay showed greater tensile strength in a briquette dried at 100 deg. C., made of the clay treated, than in a burnt brick of similar clay untreated and untempered, as is shown in the experiment of January 23rd, 1902, hereafter cited. It was therefore perhaps possible for the Egyptians to produce a sun-dried brick of greater strength from the straw-treated clay than from the same clay untreated and burned.

Returning to the laboratory notes, we find as follows:

Sept. 2: Extracted 25 grams of green sumac leaves with water and obtained liquid giving a strong reaction with ferric chloride. The liquid also produced similar effect with clay to that obtained with the tannic acid solution, at least as far as making it more liquid was concerned. An extract of 25 grams of powdered spruce bark gave a very faint reaction with ferric chloride, but its action on kaolin was very marked, being apparently more marked than that of a 0.5 per cent. solution of gallo-tannic acid. Tests were also made with tea leaves, oak bark, and catechu with favorable results.

An infusion of straw was also made up, and clay treated therewith gave results similar to those obtained with tannic acid.

Sept. 3: Four samples of kaolin weighing 10 grams each were taken, and were mixed respectively with 10 cu. cms. of the following liquids:

1. Water.
2. 1 per cent. gallo-tannic acid solution.
3. Infusion of spruce bark of unknown strength.

4. 1 per cent. solution of catechu.

Numbers 3 and 4 gave the most fluid mixtures; 3 being slightly more fluid than 4.

Sept. 7: Experiments were made with Vicat's apparatus, the 1 cm. diameter rod being used. Considerable difficulty was found in making the tests. The results finally obtained are as follows:

Harris kaolin: Rod penetrated the clay 33 millimeters in 1½ minutes. Total water in clay 38.1 per cent., or added water 28.0 per cent. Water of dehydration 10.1 per cent.

Harris kaolin from tub: Rod penetrated the clay 35 m m. in 1½ minutes. Total water 34.6 per cent. or 24.5 added water. Water of hydration 10.1 per cent.

Sept. 31: A specimen of the mixture made up Sept. 18, containing 2.5 per cent. catechu, was filtered today and filtrate tested with ferric chloride. This gave the tannin reaction. As all action in the mixture seems to be over, there is apparently an excess of catechu.

Oct. 7: Experiment made today to determine effect of tannin treatment as regards the porosity of clays. With this test was included an experiment on the effect of ammonia on clays, since it was found that ammonia produced the fluidity effect on clays. The result of the tests was as follows:

Clay.	Real Density.	Apparent Density.	Porosity (Per cent)
Harris Kaolin	2.59	1.48	43.0
Harris Kaolin, (Tannin treatment)	2.59	1.75	32.3
Harris kaolin (Ammonia treatment)	2.59	1.67	35.5

Oct. 20: A series of tests on the absorption of tannin by Harris kaolin was begun on Oct. 9, and finished today. The results are shown in the following table, where the first columns show the percentage of tannin added to the clay, and the following columns the result observed each day of treating the clear filtrate with ferric chloride:

Tannin Per Cent.	Number of Days during which treatment continued before color test was applied.									
	1	2	3	4	5	6	7	8	9	10
1.00	None	.....	.....	.....	.....	.....	.....	.....	.....	.....
1.25	None	.....	.....	.....	.....	.....	.....	.....	.....	.....
1,50	Faint Blue	Green	None	.....	.....	.....	.....	.....	.....	.....
1.75	Faint Blue	Green	Faint Blue	Faint Creen	None	.....	.....	.....	.....	.....
2.00	Blue	Faint Blue	Faint Blue	Faint Blue	Dark Green	Dark Green	Light Green	Light Green	Faint Green	Faint Green

Jan. 23, 1902: It has been found that various substances will produce the fluidity phenomenon in clays, such as beer, claret, ammonia, etc., but acetic acid and ammonium chloride will not. Ammonium carbonate produces the fluidity phenomenon, but this may be due to the free ammonia which is unavoidably present.

Result of experiments made today on tensile strength of clays gave the following results:

Specimens Dried in Air Bath. 120 deg. C.	Kilograms per sq. c. m.	No. of Tests.	Per cent. Deviation
Harris kaolin treated with 2 per cent. catechu for 3 months..	18.22	4	12.5
Harris kaolin treated with 2 per cent. catechu for 10 days....	19.75	4	16.2
Harris kaolin wetted and molded immediately.....	5.73	4	6.0
Specimens Baked. Probably 1200 deg. C.			
Harris kaolin treated with 2 per cent. catechu for 3 months...	26 91	6	7.8
Harris kaolin treated with 2 per cent. catechu for 10 days....	25.18	7	10.5
Harris kaolin wetted and molded immediately.....	17.89	7	14.3

The temperature was not determined at the time of baking but was that attainable in a muffle furnace, using anthracite coal and good natural draught, the briquettes being in contact with the fuel; the conditions being similar to those under which I have repeatedly melted cast iron. It probably reached 1,200 deg. C.

The following table of results, obtained with above mixtures, will indicate clearly the effects products:

Harris Kaolin. In Briquettes.	No. of Tests.	Mean Breaking Load per sq.cm.in kilos.	Ratio	Absorbs per cent. of water.	Linear Shrinkage per cent.
Untreated, Dried at 120 C.....	4	5.73	1	....	6.00
Treated with 2 per cent. Catechu for 10 days, Dried at 120 C.....	4	19.75	3.45	....	....
Treated with 2 per cent. Catechu for 3 months, Dried at 120 C.....	3	18.22	3.18	....	4.38
Untreated, baked.....	7	17.88	1	25.7	7.50
Treated with 2 per cent. Catechu for 10 days, Baked	7	25.18	1.45	....	....
Treated with 2 per cent. Catechu for 3 months, Baked	6	26.90	1.50	17.9	6.25

Notwithstanding the large mass of accumulated evidence

of the novelty and value of the discovery, I still wished for further proofs of the truth of the matter before making any public announcement. Time passed by until January, 1903, when I concluded to submit the matter to some recognized authority. I anticipated some difficulty in procuring the desired assistance, owing to my being a perfect stranger in the art, and the rather startling nature of my claims. I was fortunate, however, in securing the co-operation of Dr. Heinrich Ries, before whom I laid the results of my investigation, supplemented with a demonstration of one of the effects of treating clay with gallotannic acid. Dr. Ries was convinced that the subject was worthy of his consideration, and undertook a series of experiments on lines similar to those I had made, for the purpose of determining the truth of my deductions.

Dr. Ries's first report was as follows:

Ithaca, May 18, 1903.

Mr. E. G. Acheson.

My Dear Sir: I beg to submit herewith my report of the experiments which I undertook for you, to determine the effect of tannin or other organic compounds on the physical properties of clay.

While these experiments were undertaken with the purpose of testing the accuracy of your conclusions and to see whether my results were corroborative of yours, I may state that until the work was nearly completed I was acquainted only in a general way with the details of your trials. I am glad that this was so, since I feel that I was able to proceed without any bias, and that as my results have corroborated yours, the various proofs can with reason be considered all the stronger.

The facts that I started out to determine were the following:

Do tannins or other vegetable compounds added to clay affect

1. The amount of water necessary for tempering?
2. The amount of water necessary to make a slip?
3. The air shrinkage of the clay?
4. The total shrinkage of the clay?
5. The tensile strength of the dried and burned material?
6. The degree of cracking in drying, if any occurs?
7. The color of the ware when burned?

8. The hardness of the green and burned clay?
8a. Effect on the plasticity?
9. If these effects are produced, what is the nature of the action of the tannin?

Modifying agents used.

The materials which I experimented with were

1. Gallo-tannic acid.
2. Catechu.
3. Emulsion of straw.

Clays employed.

The clays chosen for the tests were the following:

1. Kaolin from the Harris mines near Dillsboro, N. C. A whitish burning china clay of low plasticity, and one which burns to a rather porous body at moderate temperatures.

2. Kaolin from the Burgess Kaolin Co., at Hockessin, Delaware. Burns white with a slightly yellowish tinge, lacks in plasticity and has moderately high air shrinkage.

3. Kaolin from southeastern Pennsylvania (probably South Mountain district.) This is a whitish clay of poor plasticity, very low tensile strength, and cracks very badly in drying and burning, no matter what precautions are taken.

4. Ball clay from Florida. Plasticity fair, color white when burned, but tends to crack if too much is used in a pottery mixture.

5. A No. 1 fire clay from New Jersey. A clay of low tensile strength, but quite sticky and refractory. When used alone it cracks badly in drying and burning.

6. A white burning clay from Georgia. A material of low plasticity and tensile strength but very refractory.

7. Washed ball clay from Edgars' pits at South Amboy, N. J. This again is a clay of low tensile strength, and one which when used alone cracks badly in drying and burning.

8. A retort clay from Berry's pits at Woodbridge, N. J. Clay of dense burning quality but not high tensile strength.

You will see from an examination of the above that I selected a series of clays that were deficient in some of their physical properties, and in some cases so poor as to severely test the efficacy of the tannin treatment. As you can also see from

what follows, I was not able to effect a positive cure in all cases, but a decided improvement was at least visible.

In all about forty samples of clay were mixed up, and where the clay was not received in a powdered condition it was ground up sufficiently fine to pass through a sieve of 20 meshes to the linear inch.

In mixing the tannin with the clay, I adopted the plan in my earlier experiments of stirring the powdered tannin with the clay and then adding water, but in all the latter ones, I dissolved the tannin in the water first and then added it to the clay.

Where the treated clay was to be molded at once, it was mixed with water to a mass of sufficient plasticity for molding, and this was then thoroughly kneaded for fifteen to twenty minutes. I am inclined to think that in the majority of cases this is as effective as allowing the material to soak for ten days, because the through kneading allows the tannin to thoroughly permeate the clay mass.

Now to take up the ten points enumerated in the beginning of my report.

1. *Amount of water necessary for tempering the clay.*

The addition of either tannin or straw emulsion to the clay diminished the amount of water that was necessary to produce a sufficiently plastic mass for molding.

Clay and Treatment Given.	Per cent of water by weight.
Harris kaolin alone required	40.00
Harris kaolin with ½ per cent. gallo-tannic acid	30.00
Harris kaolin with 1 per cent. gallo-tannic acid	27.00
Harris kaolin with 2 per cent. gallo-tannic acid	25.00
Harris kaolin with ½ per cent. catechu	28.50
Harris kaolin with 2 per cent. catechu	25.00
Pennsylvania kaolin alone	43.12
Penn. kaolin with 1 per cent. gallo-tannic acid	35.00
Penn. kaolin with 2 per cent. catechu	30.00
Hockessin kaolin alone	41.50
Hockessin with 2 per cent. catechu	36.00
(somewhat softer than the preceding.)	
Florida ball clay alone	33.50
Florida ball clay with 2 per cent. catechu	33.00
(mixture wetter than preceding so that less water could have been used.)	

These it seems to me seem to show the effect of tannin in decreasing the amount of water required to make a paste.

2. *Amount of water required to produce a slip.*

For this the clay was mixed with water until its consistency was that of thick cream. This was tried on several of the samples that were to stand for ten days.

Clay and Treatment Given.	Per cent. of water by weight.
Florida ball clay alone when mixed to cream required	114.0
Same, with 1 per cent. gallo-tannic acid	93.7
Same, with straw emulsion	93.7
Same, with 2 per cent. catechu	83.0

A similar effect was noticeable on other clays.

3. *Since the amount of water added with tannin present is less,* there will be less water to evaporate from the clay, and there should consequently be a decrease in the air shrinkage. This point was determined on several clays, as follows:

Clay and Treatment Given.	Air Shrinkage. Per cents.
Harris kaolin, alone	5.00
Same, with ½ per cent. gallo-tannic acid	4.6
Same, with 1 per cent. gallo-tannic acid	4.6
Same, with 2 per cent. gallo-tannic acid	3.3
Same, with 2 per cent. catechu	4.
New Jersey retort clay alone	11.
Same, with 1 per cent. catechu	6.
Same, with 1 per cent. gallo-tannic acid	8.
Same, with straw emulsion	8.
Florida ball clay alone	10.
Same, with 1 per cent. catechu	9.
Same, wiht 2 per cent. catechu	8.3
Hockessin kaolin alone	6.
Same, with 2 per cent. catechu	5.

Total shrinkage of the clay.

This was determined by burning several bricklets at different temperatures. Total shrinkages of the Harris kaolin at several temperatures are given below.

Clay Mixture.	850 C.	Cone 1.	Cone 5	Cone 8.
Harris kaolin, alone	6.3	7.6	10.	15.
Same, with ½ per cent. gal. tan	5.3	6.6	10.	...
Same, with 2 per cent. gal. tan	5.3	5.3	...	...
Same, with ½ per cent. catechu	...	...	...	13.3
Penna. kaolin alone	...	...	...	16.6
Same, with 1 per cent. gal. acid	...	...	...	15.3

5. *Tensile strength.*

In the "green" or unburned clay, the effect produced by

the tannin was remarkable. Two lines of experiment were tried. In one the briquettes were molded as soon as the clay, water, and tannin had been mixed; in the other the whole was allowed to stand for ten days. I am inclined to think that thorough kneading is as effective as ten days' standing.

Results obtained by molding at once were as follows:

Clay and Treatment Given.	Tensile strength lbs. per sq. in.
Harris kaolin untreated	65
Same, with ½ per cent. gallo-tannic acid	84
Same, with 1 per cent. gallo-tannic acid	90
Same, with 2 per cent. catechu	160
New Jersey fire clay, straight	30
Same, with 1 per cent. gallo-tannic acid	36
New Jersey retort clay, straight	61
Same, with 1 per cent. catechu	67
Same, with straw emulsion	125
Florida Ball Clay, straight	157
Same, with 1 per cent. catechu	179
Same, with 2 per cent. catechu	267
Hockessin kaolin, straight	61
Same, with 2 per cent. catechu	188
Penn. Kaolin, straight, (cracked so it could not be tested)	...
Same, with 1 per cent. gallo-tannic acid	36

The following results were obtained on mixtures which had stood several days.

Clay and Treatment Given.	Tensile strength lbs. per sq. in.
Harris kaolin with 1 per cent. gal. tan. acid, 10 days	101
Pa. kaolin with 2 per cent. catechu, ten days	60
N. J. fire clay, 1 per cent. gal. tan. acid, 8 days	38
N. J. retort clay, 1 per cent. gal. tan. acid, 10 days	80
Same, 1 per cent. catechu, 8 days	111.5
N. J. ball clay, 1 per cent. catechu, 10 days	45
Georgia white clay, 1 per cent. gal. tan. acid, 10 days	65

These tensile strength figures usually represent the average of twelve tests. In some cases as many as fifteen or sixteen were tested. In the burned samples two clays were tried, viz.: the kaolin from North Carolina and that from Hockessin, Del. The treated ones in both cases contained two per cent. of catechu. The briquettes were burned at 800 deg. C. as determined with a

thermo-electric pyrometer, and they were held at that temperature for one hour. This yielded the following results:

Clay and Treatment Given.	Tensile strength lbs. per sq. in.
Harris kaolin, straight	160
Harris kaolin, with 2 per cent. catechu	275 maximum 300
Hockessin kaolin, straight	115
Hockessin kaolin, with 2 per cent. catechu	195

These represent the average of six tests each. The briquettes when put into the furnace showed a decided difference in color, but in burning this disappeared. It will be noticed on examining the fractured surface of the briquettes that the center, corresponding to the interior of the brick, is rather white in color. I do not believe that this white part represents bleached tannin, left in the clay, because at 850 deg. C, the temperature at which the briquettes were burned, the tannin compounds would certainly have been destroyed. What I believe is that the tannin in burning off, took up oxygen from the atmosphere of the furnace, and prevented the iron in the clay from getting any and thereby becoming oxidized, and hence the interior of the clay piece remained white, due to reduced iron. If, now, after the tannin had been driven off, the briquette is kept hot for a while, the iron begins to oxidize, this action beginning at the surface and extending inwards, but the briquettes were not left in the furnace long enough to enable the iron to change all the way to the center of the clay piece.

If the clay is burned harder than is necessary to burn off the tannin, the tensile strength of the treated and untreated clay seems to be more alike.

6. *Cracking in drying.*

Three of the clays used show air cracks to a most marked degree, so that it is difficult to find a briquette sufficiently free from flaws to test its tensile strength. In the case of the Pennsylvania clay I found that the air cracking was diminished but not entirely prevented by the addition of catechu. The New Jersey fire clay and the ball clay from the same state also showed signs of improvement. There are clays which crack so badly that I doubt if any amount of tannin could improve them, as for example the Klingenberg clay from Germany. Such clays are worthless if used alone, but possess high bonding powers

when sandy materials are added to them, and it is possible that if the tannin were added to these mixtures, that their tensile strength might be raised.

7. *Color when burned.*

The temperature at which all traces of tannin seem to have disappeared from the clay seems to be about 850 deg. C., for at this heat no coloring effects seem to be left, although they are present at as high a temperature as 700 deg. C., as can be seen from the bricklets accompanying this report. However, the temperature of 850 deg. C. is a much lower one than the clay would ever be burned at in practice. Some clays turn an inky blue when treated with catechu, as can be seen from one of the air dried samples, but this coloration burns off entirely, and in no way affects the color of the burned ware.

8. *Hardness of the green and burned clay.*

In the green condition the treated clay is more solid and harder than the untreated material. In the burned material I found that the treated clay in the case of both Hockessin and Harris was so much harder than the untreated, that the former would scratch the latter.

8*a*. *Effect of tannin on the plasticity.*

There is up to the present day, unfortunately, no satisfactory means of measuring accurately the amount of plasticity which a clay may show, and about the only way to judge of the degree shown by any clay is to feel it. It seems that the tannin increases the plastic feeling of most of the clays tested.

9. *Cause of the action of the tannin.*

It is but natural to speculate regarding the change which the tannin compounds produce in the structure of a mass of clay so as to materially increase its strength and plasticity. My theory was that the probable effect of the tannin was to deflocculate the clay particles, or in other words to break up the compound grains formed by the cohesion of a number of small particles, and convert them all into single or individual grains. To test this theory I mixed up a little clay in water, and found on examining it under the microscope, that many of the grains were compound or flocculated. I then took the same amount and stirred it up with some gallo-tannic acid. After letting it

stand for a while I examined it again, and found that most of the compound grains had disappeared, and that the clay was in a puddled condition.

As regards the retention of the tannin by the clay, a sample was taken of the slip of clay containing gallo-tannic acid after it had been standing for several days, and put through a Pasteur filter under pressure, so that a clear filtrate could be readily obtained. This filtrate, when tested with ferric chloride, gave no trace of reaction. When I took some of the slip and added ferric chloride to it the reaction was very strong. This would indicate that the clay had the power of abstracting the tannin from the water and retaining it in its pores. There does not seem to me to be any objection to this, as the material burns off.

I think that this covers all the points, and it is a matter of great satisfaction to me that I have been able to corroborate the preliminary experiments that were made by you.

Respectfully submitted,

Heinrich Ries.

The experiments herein outlined by Dr. Ries, and the conclusions he arrived at, were confirmatory of my work. I had found that 2 per cent. of gallo-tannic acid or catechu produced the maximum effect in about ten days. Dr. Ries suggests the working or pugging of the clay and water as a means of shortening the time, and I doubt not he is right on this point.

I had found in my experiments that the value of the treatment gradually grows smaller as the article in burning is carried towards a higher temperature. In fact, the maximum effect probably exists up to 100 deg. C., but it is still quite noticeable up to and beyond the temperature sufficiently high to burn off the tannin.

Dr. Ries's comment on the deflocculated state of the treated clay is interesting, in view of the fact I discovered that clay slip, when treated with gallo-tannic acid, would pass through a filter paper even after thorough digesting, whereas the clay in the untreated condition was entirely retained in the filter.

Under date of June 12, 1903, Dr. Ries made a report of tests on a mixture used by a well-known pottery, in which he says:

"I made the material up into a slip sufficiently thin to go through an eighty mesh sieve. With water alone it required 1750 cc. for four pounds of the material. With 2 per cent. catechu it took only 1250 cc. to mix the same amount up thin enough.

"Tests of these same mixtures for tensile strength showed for the air-dried briquettes 38 pounds per square inch in the natural condition, and 210 pounds per square inch for that treated with 2 per cent. of catechu."

. . . . . .

To determine the effect of leaving out the ball clay and adding tannin to mixtures used in white ware, Dr. Ries made a set of experiments, and under date of October 28th, 1903, reported as follows:

. . . . . .

"The mixtures experimented on were of two kinds. 1, white earthenware body and 2 a sanitary ware body. The former does not vitrify at cone 9 and the latter does.

"*White Earthenware Body.*—A mixture was made up consisting of flint, spar, North Carolina kaolin, and English ball clay. These ingredients were carefully mixed, and molded into discs for burning, and also into briquettes for having their tensile strength tested. The average tensile strength of such a mixture was 55 lbs. per square inch. A disc of the mixture three-eighths inch thick and three and one quarter inches diameter burned at cone nine to a dense but not vitrified body without warping.

"A second mixture was then made up in which the ball clay was left out and kaolin alone used in conjunction with the flint and spar. This felt somewhat less plastic, and had an average tensile strength of only 39 lbs. per square inch. Its shrinkage was also somewhat less.

"Following this a mixture was made the same as the preceding but with 2 per cent. of catechu added to it. Without allowing it to stand the material was molded and its tensile strength tested. The latter was 125 lbs. per square inch. The mixture with tannin was more plastic to the feel than the ball clay mixture, and also showed an elasticity which the former did not possess. The tannin, of course, produced a strong coloration of the green material, but burned off entirely at a low tempera-

Now, I will thin both mixtures with water, and pour into these two filters which I have prepared, using the imported French filter paper. (*Stirring each mixture and pouring into separate filters.*) We will now leave them to run through.

Last fall I received from London clippings from English papers with great scare headings, the articles going on to state that England was going to lose its great potteries to America, because a syndicate had been formed to purchase the great ball-clay mines of England, giving figures offered by the American syndicate which seemed almost fabulous to me. In the light of my experiments, I do not consider that they have so much value.

(*Turning to filters:*) You will notice that this (*referring to filter into which had been poured the solution of natural clay*) is perfectly clear, or nearly so. It would have been entirely so had I not overflowed the filter when pouring in the mixture. This (*referring to other filter*) you see is milky, showing decrease in size of grain of the clay; that is, deflocculation.

Regarding the remarkable increase in hardness in dried samples of clay which have been treated with tannin, I would like to show you these:

Here are two pieces (*exhibiting same*) made from clay from the Harris mines. They are the same in every respect except that one has an addition of two percent. of tannin. The material treated with tannin remains somewhat dark colored at low temperatures, but as the temperature is increased the liberated carbon is removed, and it finally becomes perfectly white. (*Takes a small stiff brush and brushes the surface of each piece in turn.*) You will notice that the material of this piece (*indicating one without tannin*) brushes away rapidly, making a cloud of dust, while in the other case there is no impression made.

Mr. W. D. Gates: I received an advance copy of Mr. Acheson's paper, and was greatly interested. It struck me at first as being most novel.

Concerning the "Egyptian" part of it, I recalled, as possibly some of you do, that twenty years ago a man obtained a patent for mixing sawdust with clay. I had an interview with him while he was pursuing his experimental work. He told me that being at one time unable to procure sawdust, he mixed some

chopped straw with his clay. It was found that when the clay had been through the auger machine it was necessary to cut it with a saw, as the action of the augers had been such as to range the straws all horizontal. He had not hesitated to get a patent on the sawdust process, and Pharaoh not objecting, he got one on the straw also. I do not believe that he realized that he obtained a chemical action by mixing the straw with the clay. I think we all get results we do not understand. While there may be chemical action from soaking straw and using the solution in clay, it is another question whether the Egyptians knew it.

When I received the paper, I immediately began to do some experimenting. We obtained catechu in a large, square package, two or three feet square and some six or eight inches thick. It was done up in a sort of a woven blanket and covered with bagging. It does not look like that (indicating sample which Mr. Acheson had placed on table.) That which I have cost me seven cents a pound in the original package. It is a resinous-looking substance with a glassy fracture. Here is what we obtained (exhibiting sample of clay product). It is a dry clay body, made of grog and raw clay. We started with two per cent. of the catechu, but did not get it all dissolved, because we were in a hurry. Our hasty experiment corroborates what has been said, as to reducing quantity of water required. It feels in the hand very hard, almost like iron. I do not know what the change is, whether chemical action or not.

As I said before, this question of handling clays is vital to all of us, and the possibility of decreasing the amount of water necessary in mixing is most important, for it costs money to extract that water and is a hazardous operation besides. The same results as those produced here, may, however, be produced by the addition of three-eighths of one per cent. of silicate of soda. I have never experimented with this as thoroughly as I intend to.

In speaking of the rapidity of the effects of the tannin treatment, Mr. Acheson stated that it could not be due to bacteria on account of the quickness of the result. In a hasty examination of this piece in which catechu was used, I found a great quantity of bacteria, and also in that simply mixed with water. I confess

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I thought at first that it might be that the bacteria might be the cause rather than the catechu, and I am not yet satisfied that such is not the case.

Note submitted subsequently by Mr. Gates for printing; not a part of the discussion on the floor of the meeting.

Upon returning to my experiments I find, *First*: We took a clay body which had been working excellently, and mixed a little more than a ton with 2 per cent. of catechu, and with it pressed a large bath tub which required about that amount of clay. This same body, without the catechu, had been used very successfully in making bath tubs, handling well and drying without cracking. Instead of the walls and partitions standing up better, as I expected, they did not act nearly as well. The tub sunk down badly when finished, dried very slowly indeed, and finally when dry was seamed and torn with great cracks, and had to be broken up and thrown away.

The whole body was a brown color, the surface a chocolate brown, and it seemed to me as though it had a wax coating which shut the water in and prevented drying.

Second. I also had a number of tiles 8 x 8 x 1 inches thick, which were slipped with different slips and some enameled. These warped considerably in drying, the brown color extended through the slip, and also through the enamel. The enamel was harder and much less liable to brush off from the green ware. When these came from the kiln, however, all the light colored slips were discolored, and the surface was not so good as in those without the catechu, being in most cases cracked. In the enameled samples, the enamel had crawled very badly, leaving about half the surface of the tile bare and of a dirty disagreeable color, whereas the enamel worked perfectly on the tiles without the catechu.

This was a great disappointment to me. On first reading the paper, I had great hopes of the process, but I am done with it. My "bale" is for sale. It may do for adobe, but we burn our wares.

Mr. Acheson: That the result is not due to bacterial action is probably more conclusively proved by the fact that I have

produced it, as well as I have ever done it, with a boiling infusion of straw. I do not believe that bacteria will stand such treatment. The clays, however, were not sterilized.

Dr. A. S. Cushman: When Mr. Acheson published his specifications for a patent, I did considerable experimenting with tannic acid, and I found that it increases the binding power, but I did not find that it produces the same effect on all clays. I think we should guard against drawing too broad conclusions all at once concerning a new proposition. It may increase the binding power two or three hundred per cent. on one clay and have a disappointing effect on another.

Speaking of the question of bacteria, and its supposed bearing on the plasticity of clays, I suggested in a paper published last year that you may be putting the cart before the horse. A certain condition in the clay may make bacterial growth possible, instead of bacteria causing that condition.

I have been as much interested as any one in the discovery of the effect obtained by the treatment of clay with tannic acid. But in these experiments tannic acid might be replaced by many other inorganic substances and the same results secured. With sodium silicate we get the same effect, and I have gotten the same effect with numerous colloids. Tannic acid is a typical colloid. The experiments made by Dr. Ries confirm those made in my laboratory, showing the actual disappearance of tannic acid. Does it disappear by adherence to the granular particles present in the clay? No. It disappears inside of them. Into what? Into the micellian structure. It "stuffs" the clay and increases its density. What is the result? After you treat the clay with tannic acid it will not take up so much water.

I am not trying to decry the importance of Mr. Acheson's discovery. If it is useful to clay workers it is a very important discovery, and I congratulate Mr. Acheson on having made it. But I do think we will find a great many other things which will work in the same way.

Mr. J. H. Hasburg: When I heard of this invention last April I was very much interested to know exactly what action Tannic acid had on the different materials composing clay.

I prepared chemically pure and fresh precipitates of alu-

minum hydroxide, silicic acid, ferric hydroxide, and carbonates of lime and iron.

One portion of each precipitate was dried at 100° Fahr., another at 350° Fahr. and a third at 700° Fahr. This gave three samples of each precipitate, each in a different state of hydration. Each was to be treated with a specific amount of Tannic acid and the results carefully noted.

I selected the iron content to begin with as chemical changes could be readily noted by changes of color which might not be the case with the others. I found that Gallic acid did not act on ferrous salts except in the presence of lime. Gallo-Tannic acid acted on both ferrous and ferric salts. By treating freshly precipitated carbonate of iron with Tannic acid, I found it absorbed or took up about one-fifth its weight of the acid. Here I was compelled to abandon further research and have not had time since to finish the work.

It was my idea in drying the precipitates at the different temperatures especially the ones at 100° F. to keep them in as near a jelly like (colloid?) condition as posible and carefully note the difference in absorption of acid between the 100° and 700° precipitates.

Mr. A. S. Watts: A few years ago I had occasion to take up the subject of strengthening a white ware body, a body which had been giving a great deal of trouble from cracking, and I naturally turned to available data on the subject. In previous meetings there had been discussion in regard to using vinegar and beer and such things, added to the body to produce fermentation. I tried a few experiments on this line but did not get much satisfaction and soon gave it up.

Later, I had occasion to repair the wood lining of our clay cellar which had given out. It was impossible at that time to get any thoroughly dried timber to line it with. So we used some newly sawed, two-inch, red-oak plank. I always insisted on having the clay cellar kept quite warm, maintaining as even temperature as possible. Within a week's time after these new boards were put in, I noticed that the clay we had in there was becoming exceedingly blue where it came in contact with the boards, while back further into the clay, it remained white.

I found that a matter of three or four days in the clay cellar would start that blue coloration, and if the clay was allowed to remain two weeks in contact with the boards, the color would penetrate a foot into it. This set me to thinking along that line, and I got a barrel of tan-bark. I took about a bushel of it, and put it into a tub of water, and put a small steam-coil into it, and kept the water warm for some time. I then drew the water off with a siphon, and added it to quite a large quantity of clay. In fact, at the time I thought I was diluting it too much and would probably get no result. To my surprise, it gave me a very blue clay. In the course of about seventy-two hours, the action became so strong that tiny bubbles appeared in the clay, as if violent fermenting action were going on. Whether or not such was the case, I have never investigated.

I have found that the clay thus treated became very strong, and after that I began the regular use of a very dilute solution of tan-bark. I never took the pains to determine just what the strength of my solution was; but I have found that a dilute solution of water from tan bark gives a strengthening action and I used that from two years ago last March, until the early part of last September, when I left the factory to take charge of the erection of a new pottery elsewhere. After I left, matters went into the control of other hands and I have had no opportunity of knowing whether my practice was kept up or not, but I do not think it was. After I had installed the plant which I am now operating in New Lexington, I determined to try it again, and did, with the same results. I did not claim any originality for the use of this tan-bark infusion, supposing that others were aware of it, but I did find it useful in toughening clay. I mentioned in a paper read before this Society last year, on the design of a white ware plant" I should use a lining of plank in the clay cellar, but did not give my reason, viz., that the clay would develop greater strength.

It might further interest you to know that in the first plant we were using English China clay and kaolin; but in the New Lexington plant we are not using any of these clays, but are using clays from entirely different localities.

Professor Binns: Mr. Acheson's claims are of such weight,

and if substantiated are of such importance to the working potter, that they ought to be examined thoroughly. Of course Mr. Acheson will understand that we are searching for the truth, and not criticising him. If his claim can be substantiated, it means that the potter can dispense with ball clay, with all its waste of rough material and bad color. It will also enable the potter to produce a porcelain body which at present is beyond reach under ordinary conditions of manufacture, because the koalin will not carry sufficient content of ground material, flint and spar, to get the proper composition. This process would enable us to carry a higher content of flint and spar than at present. Every practical potter knows that it is desirable to get as much ground material in as can be got with due consideration for plasticity. We get better color, lower shrinkage in drying and burning.

If this be practicable, the potter can plunge his mixture with straw tea instead of water, and if the action is immediate, he can press that tea out and use the clay in the Egyptianized form at once. I judge that probably this is the point aimed at in the process.

I want to ask concerning statements on page eight of the paper, reading: "Harris kaolin treated with 2 per cent. catechu for three months; Harris kaolin treated with 2 per cent. catechu for ten days; Harris kaolin wetted and molded immediately." Does that mean wetted with the catechu solution?

Mr. Acheson: No, sir; plain water.

Professor Binn: I would like further to ask what, in Mr. Acheson's opinion is the difference between catechu and gallotannic acid?

Mr. Acheson: I could not give exact information on that point. This effect is produced by tannin but it does not necessarily follow that we must use tannin. The extract of straw gives an effect fully equal to catechu and we know the tannin content is a small item in the extract of straw.

Professor Binns: Then I conclude the effect is not due to tannin?

Mr. Acheson: Not to tannin only. The tannin family, so far as tested, all produce it; but it is broader than the tannin

family. In the case of straw, the tannin content is entirely too small to account for the effect.

Professor Binns: Thank you. In illustration of that fact, we have on page 13 of this paper, "New Jersey retort clay, 1 per cent. gallo-tannic acid, 10 days, 80 lbs.; same, 1 per cent. catechu, 8 days, 111.5." This would show that the catechu is much more powerful than the gallo-tannic acid in increasing tensile strength, and I suggest that it is not due to the tannic acid, but to mucilaginous action. It seems to me that catechu is a form of mucilage and the increased tensile strength is due to that characteristic.

I once made an experiment with a straw infusion. Two porcelain mixtures were made up, one with straw liquor and one with water and allowed to stand for two months. There was no change apparent except that the mixture made with straw was very offensive and there was no advantage as to plasticity. But if this straw infusion does produce an effect, what is there to deny that even there we have a weak mucilaginous action?

The suggestion of bacterial growth has been laughed at a great deal. It has been brought up as a hobby several times, and discussed with freedom. Any clay when mixed with water and left by itself for ten days or a month will develop a blue color. We prepare clay as long as possible before using, and this effect is apparently spontaneous.

It has also been shown that the decrease in the amount of necessary water can be brought about by alkaline action. I admit that this is contradictory, because the gallo-tannic acid is acid, and it is shown that the action of an acid is contrary to that of alkali; but it has been said that it can be produced by sodium silicate and other alkaline solutions.

Referring to the claims made by Mr. Acheson, numbers one and three fall under the same head. "1. Decreased amount of water necessary for tempering. 3. Decreased shrinkage." Numbers 2, 4 and 6 range themselves together for the same reason. They belong apparently to one and the same cause and can be produced either by mucilaginous action of by bacterial groth. In the one case, the action might be produced instantaneously, and in the other case after a considerable period. Numbers 5 and 7. "5. Increased density annd decreased porosity," and, "7. Increased hard-

ness," do not state whether in the clay or burned form. I would like to know whether they refer to the clay or the ware?

Mr. Acheson: The ware, in both instances.

Professor Binns: These fall under one head. I venture to suggest here that vegetable solutions contain alkali and that the salt which may cause the effects claimed under Numbers 1 and 3 may also, by its fluxing action, account for the effects claimed under 5 and 7.

As to the elimination of ball clay, that depends on other things being substantiated. As to the decreasing time of tempering, that does not seem to be borne out. I do not understand Dr. Reis' statement that he believes thorough kneading as effective as ten days' standing. Does he mean the solution used in both cases?

Mr. Acheson: Yes, sir.

Professor Binns: We know perfectly well that thorough kneading is effective. That is why we pug our clays, to produce this result. It does not seem that any extraneous matter needs to be introduced, as it can be done by simply using water.

Having made these criticisms I want to say to the members and to Mr. Acheson that I most cordially hope that he can substatiate his claims. I would like quite well to see the potter put in a position to carry out these results.

One further point I want to make. Mr. Acheson said that the presence of bacteria became disapproved by the fact that the straw was boiled and used hot. I am not a bacteriologist but I rather venture to question the allegation. We hear that a great many of these creatures are almost fire-proof. Dr. Dallinger proved that he could carry them up to the temperature of boiling, and beyond without destroying life. Also, the clay itself probably contains germs and the water even if added hot would not have the effect of destroying them. There is another point which Professor Orton has pointed out: If bacterial life is present, its activity is increased by some kind of starchy food, in which it grows. It is perfectly reasonable that life should be stimulated by the presence of organic matter such as vegetable infusions. It is believed that the effect of bacterial growth is to increase plasticity. Dr. Seger claimed that acid action was generated. Mr.

Stover showed that he could not produce this effect by acid action, and Mr. Gates claimed bacteria generated a gelatinous mass which produced this plasticity in clay. We want light on these points, but Mr. Acheson's claim may possibly be referred to this cause.

Mr. Acheson: There is one point that I want to refer to. Possibly in reading my paper, knowing copies were in possession of the members, I may have omitted some portions and may not have read the portion touching upon the question as to whether this effect might be due to the mucilaginous or gummy nature of tannin. To eliminate that question and to be sure that this was not to be referred to as the cause, early experiments were made in burning of goods. It is not to be conceived that tannin exists at 800°C., nevertheless we burned goods to 1200°C, and they still showed an increased tensile strength of fifty per cent., which could not be considered as due to the existence of any organic matter. As to the possibility of tannin increasing the tensile strength 300 per cent., acting as a mucilaginous agent, that would be a pretty strong result. We must take into consideration the actual disappearance of the tannin and the probability that it was taken up by the clay particles.

Professor Binns: Mr. Acheson has shown the tannin was withdrawn. I admit that. But it appears to me that what Mr. Acheson attributes to one cause may be attributed to a variety of causes which operate in several directions. Mucilage could not exist at that heat, but there is also the presence of akaline salts which under fire become operative. I believe many causes are at work here, and while I do not question Mr. Acheson's results, I am disposed to question whether he attributes them to the right causes.

Professor Edward Orton, Jr.: I find myself very greatly interested in the colloid theory presented so ably by Dr. Cushman. I cannot add anything to the discussion in that direction, except that the theory seems plausible to me, and I hope that work will be continued by Dr. Cushman and others.

As I understand it, Dr. Cushman cites Mr. Acheson's process as typifying the working of his theory. However this may be, and without discounting the obviously strange phenomena which both Mr. Acheson and Dr. Reis have brought out, I cannot see quite so wide a future application of it to the clay working industry as

Mr. Acheson anticipates. The matter of expense is an important consideration in the clay industry. The great mass of clay wares manufactured in the world are of the cruder varieties. If we treat these crude clays with an infusion of any vegetable matter, or purchase materials like tannic acid, or catechu or similar nature to be used in quantities of one per cent., or even a half of one per cent, it will add a considerable item to the cost of preparation of clay body.

I submit that it is not feasible for the vast bulk of clay-workers to consider the use of an agent which adds appreciably to the cost of the preparation of the clay. For a plant using a hundred tons of body per day, the preparation of even a straw infusion would be in itself quite a problem. Then, further, if there is any sensible quantity of organic substance added to a clay containing much oxide of iron, you are adding another element which is of no importance at all in a small laboratory test, but becomes a matter of great importance when done on a large scale. Two per cent. of carbonaceous matter introduced into a fine grained, close-bodied, red-burning clay would constitute a very formidable obstacle to its successful burning. It could be done, but I hope to show you later in the meeting that the relation is very vital between carbon and the general behavior of clay in burning. Its introduction on a large scale, it seems to me, would be practically confined to the manufacture of white burning bodies, in which iron is so low that it would burn out without subsequent reaction or detriment.

These suggestions do not preclude the possible application of Mr. Acheson's idea to the clay industries in which white clay bodies, either natural or prepared, are used. But it would seem to me that this reducing influence in burning would practically relegate any usefulness which the discovery may have almost entirely to the white ware field.

Mr. Acheson: The matter of expense is a serious one and must be taken carefully into consideration. In my paper, I had originally a tenth claim, but I cut it out because it was a deduction, whereas I desired to confine my claims to proven facts. The tenth claim was "economy of fuel," but it remained to be proven on a large scale. But when you take into consideration the other points which have been proven, viz., increased tensile strength, de-

creased porosity, increased hardness, etc., it is shown that to obtain goods from Egyptianized clay equal to those made from that which has not been so treated, does not require the same high temperatures. It shortens the time of burning and reduces the coal bill. Taking the market price of catechu, the cost per ton of clay would probably be about a dollar and a half. One large concern has had a series of experiments made by Dr. Reis, and tho I have not seen the report, I know it was successful. They expect to eliminate their trouble with the clay cracking and get into the face brick trade by this process.

Mr. S. G. Burt: Mr. Gates says he arrived at much the same results with the use of sodium silicate that Mr. Acheson gets in using catechu. This point seems to me quite important. I have merely heard Mr. Acheson's paper read and have had no opportunity to study it but I think I am right in saying that one of his main claims is that by using catechu we are able to make a workable clay body with a much lower per cent. of water than ordinarily used and thereby decrease greatly our initial clay shrinkage and, furthermore, the clay so treated when dry is very much harder and stronger.

For a good many years potters have known that by adding sodium salts to a clay mix the same could be made liquid enough to cast, with an astonishingly low per cent. of water. The result is the same that Mr. Acheson claims for his process, that is, a shrinkage so greatly reduced that many pieces could be cast that would have been impossible without this addition of sodium salts, I have never used this process, so cannot speak from experience, but it seems quite possible that if sodium carbonate or bi-carbonate, which are ordinarily used, have this action on the clay that sodium silicate may very possibly have the same action. Now as for the clay having gained greatly in strength when dry, this the sodium silicate is peculiarly fitted to accomplish. I was appealed to by a friend some time ago to insulate for him by enameling some thin sheets of iron. I explained the difficulties thus involved and suggested a mix of clay, flint and whiting worked up with sodium silicate. This he tried and found he had a perfect insulation, so hard it could hardly be scratched with steel and one by the way which would stand red heat as well as an enamel. Now while clay alone mixed with the sodium silicate

would not give a mix as hard as this it wil give one fully as hard as the sample that Mr. Acheson has just passed around, in which he mixed catechu. Besides the result is just the same in another respect, that is, it was a thin surface film, hard as stone, while just under this the clay is just as it would be without any admixture.

This is due in both cases to the fact that the salts acting here are soluble and as the clay dries evaporation can only take place on the surface, so all the soluble salts tend to be drawn to the surface and it is only this surface that is hardened. As for the reduced cost in burning which Mr. Acheson also mentions, it hardly seems possible that this can in any way be due to the organic tannic acid which would all burn out at a low red heat. In using sodium silicate or any sodium salt, we could undoubtedly burn at a lower heat because we have in the alkaline salts a very strong flux. It is questionable whether this would be desirable in all cases, because as explained the soluble alkaline salts all having been drawn to the surface, it's there that their strong fluxing action would take place, giving us a hard and even vitrified face, while the body of the clay remained very porous. Is it possible that in adding the catechu the really active factor is some soluble alkaline salt? I would like to ask Mr. Acheson whether he has ever carried out comparative tests between catechu and alkaline solutions?

Mr. Acheson: No, but I have had considerable experience with sodium silicate in other lines, and first, of course, you must carry your product to the point of vitrification to get the benefit of the sodium silicate, which is otherwise soluble. You can make a strong article, but you must keep it dry.

Mr. Burt: It can be made perfectly insoluble.

Professor Binns: In connection with Mr. Acheson's title, I think a reference to the Book of Exodus will show that the stubble was considered inferior to the straw. But I know it was affirmed some years ago that an Egyptian explorer believed he had secured a sample brick made with straw and one made with stubble, which he packed and shipped home. When unpacked, it was found that the one made from straw was perfectly sound, while the one made from stubble was broken into pieces. If that is so, it rather disposes of the theory that the Egyptians used an infusion of straw, but goes to prove that they used straw because of its long fibre, and when forced to use stubble they found it not so good.

Mr. Stull: In an experiment I made in the laboratory of the American Terra Cotta Company, I found it took a little over one hundred pounds of water to mix a hundred pound batch of a certain body I was making. By using silicate of soda, I cut the water to eighty-three pounds, using three-eighths of one per cent. of the silicate.

Mr. Hasburg: If it is a fact, as shown by Mr. Acheson, that this tannin treatment results as claimed in his summary, the increased density of the clay means increased conductivity of heat. The solution of the smaller amount of fuel required may lie in that fact.

Note submitted subsequently in writing. Not a part of the discussion on the floor of the meeting.

Mr. Charles Weelans: What I have to say is founded upon personal experience and practical knowledge and not upon theoretical considerations. This will justify me, perhaps, in offering it in this convention.

Mr. Acheson, I understand, by the use of catechu or tannic acid in connection with clay bodies lays claim, among others, to the three following beneficial effects:

First. That it toughens the clay body, thereby increasing its plasticity.

Second. That is hardens and thereby increases the tensile strength of the clay.

Third. That when a small per cent. is used much less water is required to temper the clay for us.

With reference to the first point I would like to say, that many vegetable mixtures have long been known and used by the potter, which accomplish this identical result. Gums, glues, and gelatine, if used properly, will bring about these results to a remarkable degree, but however simple and practical their use, the average potter resorts to them only for special bodies made up for especial uses.

Years ago in making up a batch of clay for casting purposes in which we always incorporate a gum mixture, a mistake was made in that we used a material which we took to be the usual gum mixture, but which turned out to be, while in appearance the same, entirely different. Without explaining how this mistake was

made, suffice it to say much trouble was occasioned thereby, as we could not proceed with our work. Our body being a porcelain body, short in nature, as the potter calls it, would not, despite fine and long grinding, hold together even to allow the casting of a small cream pitcher. The mistake was discovered later and rectified, and our trouble was overcome, for we then did with ease what was utterly impossible before, without this gum preparation.

With reference to the second point, I may say that this gum or glue mixture, also hardens the clay, increasing its strength materially. It is common knowledge among potters that ware casted from a clay thus prepared, when made in small articles of about an eighth of an inch thick, is very hard and strong when thoroughly dry, and there is, therefore, much less loss in the clay state in this ware, owing to the fact of adding this mixture. In addition, it prevents much cracking and permits the joining of different parts of ware together—its powers of adhesion being much increased thereby. I have known where pieces of ware have been taken from moulds in badly broken condition (due to moulds being used too frequently and becoming thoroughly saturated with water) and, though they were important pieces, they were patched up and finished, passing successfully through the kilns no worse for their mishap. This would be practically imposible with ordinary porcelain ware, made up without this gum mixture.

With reference to point three, that the use of catechu makes less water necessary in mixing of the clay body, it may be said that in our methods we have also noticed this result. We have always attributed it, however, to the fact that gelatinous matter used is immediately taken up by the alumina in the body, reducing its power of absorption and, hence, requiring less water for each mixing. In fact, we have noticed a perceptible difference in this regard, when the main material used is glue, instead of gelatine or gum. We had weighed two mixings of equal density, the slip weighing 30 or 32 ounces to the pint, and by testing with the hydrometer, proved the density to be about the same, but after using a glue mix in the one instance, and a gelatine mix in the other found after the additions were made that the density of the mixings had become widely different. This we have always attributed to the differing powers of absorption of the materials employed.

In conclusion it would seem to me had Mr. Acheson put in an apprenticeship in the pottery business, this discovery would not have seemed to him a discovery at all, in that the many beneficial effects which he attributed to the use of tannic acid would have been found to be equally well developed by other materials long known and used by the potter.,

Notes submitted subsequently in writing and not a part of the discussion on the floor of the meeting.

Dr. Heinrich Ries: I have read the remarks made by the various members on this paper and since I made a number of experiments for Mr. Acheson in connection with this work there are a few points on which I can, perhaps, offer some explanation. It is a well known fact, of course, that bacterial action is supposed to influence the plasticity of clay to a marked degree and this idea has gotten such a firm hold in the minds of many that whenever any artificial method of improving the plasticity of the clay is suggested it is, perhaps, natural that persons should suggest at once that it is nothing but bacteria. When Mr. Acheson came to me and informed me of the experiments which he had been making, he told me that it had been suggested to him by some persons that it was not the tannin but bacteria that was causing these effects. I, consequently, endeavored in the very beginning to make some experiments which would eliminate the bacterial element from the work and in several preliminary tests the precaution was taken to use distilled water in which the tannin was dissolved at the temperature of boiling and the clay which was treated with this tannin was previously heated to 120 degrees for a whole day in a hot air bath. From the mixture of these sterilized materials the same results were obtained as in the case of unsterilized materials.

In regard to the method of adding tannin I would say that several methods were tried. In one case the powdered tannin was mixed with powdered clay and the water then added and the whole thoroughly kneaded. In a second case, the tannin was first dissolved in boiling water and added to the clay in that manner. In a third case the dry powdered tannin was mixed with the clay, the water added to this and the whole mass mixed up in a ball mill. There was very little difference in the results obtained by these three methods, although the ball mill mixture gave perhaps slightly better results.

In regard to Profesor Binn's question about the decreased time required for tempering, I would state that it seemed to me in most cases that a thorough kneading of the mixture produced nearly as great increase in the tensile strength as was obtained by a small amount of kneading and then allowing the mold to stand for ten days or two weeks. In cases where the material was allowed to stand, the clay had sufficient water added to it to produce a rather thin, pasty mass, not as thin as the slip, however.

It seems to me that Mr. Acheson's position has been slightly misunderstood. As I understand it, he does not claim that tannin is the only thing that will produce all of the results mentioned in this paper. As Mr. Burt has stated, it is, of course, well known that silicate of soda and carbonate of soda will decrease the amount of water required for mixing a clay. Whether or not they will increase the tensile strength is a point which I believe remains to be demonstrated. It is a fact, however, that the addition of a small per cent. of tannin did produce the results mentioned in Mr. Acheson's paper. It is not claimed that all clays will be equally improved by the use of tannin, in fact they are not all equally affected, and the effect of the tannin appears to decrease with the increase in the sandiness of the clay. It also seems to me that if Mr. Acheson's results are found to be of commercial value, it will be in connection with white ware bodies.

THE COLLOID THEORY OF PLASTICITY.

By Allerton S. Cushman, A. M., Ph. D.

In a recent article[1] the writer published the results of an investigation which led to the conclusion that the plasticity of clay was due to a colloid condition of the fine particles, or of some proportion of the particles which go to make up the clay mass. These amorphous, inorganic particles possess a submicroscopic porous structure. They absorb water eagerly and gradually assume the coherent condition which causes in the wet mass the quality we call plasticity, and in the indurated mass, binding power. It is perfectly true that a high plasticity does not invariably accompany a high binding power, and vice-versa, but as will be shown later on in this discussion, there are many inorganic colloid substances and modifications which differ in properties, just as do the organic colloids. Gelatine, egg-albumin and common glue are all classed as colloids, but the degree of binding power which they produce on induration, is of a very different order. Moreover, it need hardly be said that we are here considering heterogeneous mixtures and not chemical compounds of constant composition and with definite properties. The shape, size, hardness, toughness, chemical composition, physical modification and degree of intimate admixture of the constituent particles are among the important qualities that affect the texture and presumably the technical value of clays.

Before proceeding further with the presentation and discussion of experimental evidence in favor of the colloid theory of plasticity, an effort will be made to show that the trend of modern speculative opinion among clay chemists has been in the direction of this theory. In a comprehensive article[2] Zschokke has recently reviewed the whole subject and collected the various theories that have from time to time been advanced. Most of these theories are purely speculative and are not founded on

1 Jour. Amer. Chem. Soc. XXV 5.

2 Bau materialien Kunde 24, VII.

experimental evidence. Thus one authority,[1] using an ingenious mathematical argument, finds the cause of plasticity in the spherical shape of the particles, while another decides in favor of plate shaped particles which interlock.[2] One of the earlier speculations, however, that of Olchewsky, was prophetic in its accuracy, if the colloid theory is true. Olchewsky surmised that plasticity was due to the spongy porous nature of the smallest particles, which by reason of pressure arrange themselves into a sort of felt. The deformability and shrinkage were accounted for by the water which fills the capillary interstices, but also acts as a lubricant, wetting the surface of the particles. Daubree had previously noted that feldspar ground wet gradually assumed a plastic condition, whereas dry ground feldspar simply wetted was not at all plastic. Olchewsky suggested that the same action took place in nature, and that the porosity of the particles was the result of the solution and leaching out of the alkalies. Ostwald has adopted a similar view and in his Lehrbuch der Technische Chemie we read that plasticity depends upon a porous sponge-like structure of the fine particles which is measured by the facility for taking up water. Arons,[3] Bischof, Seger and others have suggested that plasticity might be due to the presence of hydrated aluminum silicate in some especial form, and writing in 1877 Seger[4] adds to this his belief in a molecular arrangement of the fine particles and considers the possibility of the arrangement having been originally fixed in the structure of the parent rock. Zschokke points out that plasticity is a quality shared by many diverse substances. Thus many metals while cold, almost all metals while hot, glass and even ice are more or less plastic. In this connection it is interesting to note that Graham in 1862[5] showed that metals, glass and ice were particular examples of substances capable of assuming colloid forms.

In May, 1902, Paul Rohland[6] published a short note in which he suggests that plasticity in clay is a colloid quality. He

1 Notizblatt des deutschen Vereins fur Fabrikation von Ziegeln Thonwaaren Kalk und Cement. Berlin 1873, 4 167.
2 Cooke, Clays of New Jersey, N. J. Geol. Surv. 1878.
3 Dammer Chem. Tech. Bd. I.
4 Thonindustrie Ztg, 1877, 37.
5 Lieb Ann Cl. 1862.
6 Zeit. Anorg. Chem. XXXI 1.

points out that colloid substances in contradistinction to crystalloids are those which possess to a greater or less degree, plastic characteristics, especially as to formability and shrinking on induration. A year later Van der Bellen,[1] in presenting a new method for determining the plasticity of clay, accepts the colloid theory, and states that as the purest clays and kaolins are undoubtedly aluminum salts of meta-silicic acid, the varying degree of plasticity will depend on the presence of a colloid modification in the structure of the clay particles.

In this country Heinrich Ries has hinted at the theory in the following words, published in April, 1902:[2] "If an exceedingly plastic clay is examined under the microscope, it is found that in addition to the regular particles of a scaly nature, there may be a large number of extremely minute spherical structureless particles which may be in the nature of colloids."

Having shown by the above citations that many of the authorities on clays are hospitably inclined toward the colloid theory, it is proper to say here, that the writer was led into advancing it quite independently, and as the result of prolonged laboratory investigation.

One of the important tests which has been developed in the study of road materials is that of the binding or cementing value. In this test[3] a quantity of rock is ground to powder in a ball mill, sifted through a hundred mesh sieve, and made into a stiff dough with the requisite amount of water. From this dough small cylindrical briquettes are made by means of a specially designed hydraulic press. After thorough drying, these briquettes are broken by impact in a testing machine, and the cementing value is indicated by the number of blows of a 1 kilogram hammer falling one centimeter, which is required to produce failure in the test piece.

As records of this test multiplied, it became apparent that the binding power is an exceedingly variable quality even in the same variety of rock, and it became a matter of the greatest interest and importance to understand the cause of the phenomenon. As clays are in the final analysis nothing but rock dusts,

1 Chem. Zeitung 36, 1903.
2 Md. Geol. Survey, Report on the Clays of Maryland.
3 Bull. No. 79, Bureau of Chemistry, U. S. Department of Agriculture.

more or less modified by the action of water, and as a rule exhibit binding power to a much greater extent than freshly ground rock, is seemed reasonable that a clue might be found in this direction. The first question which presented itself was, what is the essential difference between a natural earthy deposit such as clay, and a mechanically ground rock powder. Clays to be sure are in many cases very old, but they are not as old as the crystalline rocks from which they were born. The greatest difference seemed to be that the clays have been formed by the disintegrating power of water and watery solutions, both organic and inorganic. Now it has been observed that although most of the true igneous and the highly metamorphic rocks do not bind well there are frequent exceptions, and no hard and fast rule can be made, such as that sedimentary rocks make better binding material than those of crystalline origin. On the contrary, many of the traps, diabases, diorites and basalts bind excellently, while the sandstones and slates usually do not. Nevertheless, it is found that the crystalline rocks which have high cementing values, are invariably to a greater or less degree hydrated, and the microscope shows that the constituent minerals have undergone secondary alteration. If a clay is ignited, its binding power and plasticity are destroyed, and the same thing is invariably true of all rock powders. In fact, all the evidence pointed in one direction, plasticity and binding power are dependent upon some peculiar relation which finally divided material bears to water.

In following up this clue, due consideration was given to the fact that the question of the relation of water to different forms of matter, is an exceedingly complex one. Many writers on clays, while evidently struck by the fact that all plastic materials are more or less hydrated, and that by driving off all water at a high temperature, plasticity is destroyed, have none the less been puzzled by the undoubted fact that many non-plastic earthy deposits are also hydrated.

Considering now, for the time being, inorganic materials alone, it occurred to the writer that the explanation must lie in the kind of water that was present. In other words, granting that there are several different ways, mechanical, physical and chemical, that water can be related to the structure of matter,

all the facts could be explained on the assumption that only one special kind of water of combination is involved in and measures plasticity. The question then arose, could this be proved? We are accustomed to distinguish between (1) water of crystallization, (2) chemical or hydroxyl water, and (3) water of combination. The microscope in the hands of many investigators has indicated that the more plastic a clay, the less it shows a crystalline structure in the grains. In fact, all the evidence seemed to show that though hydrated crystalline matter might be represented in the grains that compose a clay body, crystalline matter has no tendency to form plastic powders. If then crystalline particles, even when highly hydrated, have nothing to do with plasticity, the question forced itself, is there any authority for believing that there exists in clays and soils any form of hydrated amorphous matter which is at the same time the cause of binding power and plasticity? Every investigator who has studied the microscopic structure of clays will agree as Dr. Ries[1] has pointed out, that structureless particles are numerous in the texture of most clays.

More than fifty years ago, following the great impulse given to agricultural chemical research by the classical labors of Liebig and his pupils, an English chemist, T. Way[2] began a series of investigations on the absorbing power of soils, which are pregnant with suggestions. The results showed that though the particles in sands and chalks absorbed water, owing to surface attraction and capillarity, clays and soils with a clay base behaved in a quite extraordinary manner. The more clayey the soil the more water it seemed capable of absorbing. But this was not all; besides water, this clay substance exhibited a greater facility for absorbing the bases contained in certain salts which were dissolved in the water. Also this action was shown to be selective, certain bases and substances being held so that they could not be washed out again. Let us hear what Way himself had to say on the subject. "Coloring matters are actually precipitated, unchanged or in the state of insoluble pigments (technically known as "lakes") by mere mixture with white clay.

1 loc. cit.

2 Royal Ag. Soc. Jour. XI 1850.

Neither to the action of capillarity, or to that of oxidation, are we to attribute the porperty of soils to retain the mineral bases and animal and vegetable ingredients of manure. The action is one indeed sui-generis, and in an agricultural point of view, of much greater importance than either of those mentioned.''. Way found moreover, *that exposure to a high heat destroyed this peculiar absorptive power of the clay substance.* Finally, so convinced was this chemist that the quality in question was due to some peculiar form or modification of the aluminum silicate which formed the clayey or impalpable portion of the soil, that he prosecuted his inquiries farther with a view to proving this point.[1] Feldspar and various natural silicates were tried, but found to be inactive; finally, however, an artificial hydrated silicate of aluminum was prepared which proved to possess all the absorptive properties to a much higher degree than clay. This compound was prepared by dissolving pure alumina in one portion of a solution of caustic soda and pure silicic acid in another. On pouring the two solutions together, there separated gradually a white flocculent precipitate, which on washing and drying had the following composition:

Silica	46.1
Alumina	26.1
Soda	15.8
Water	12.0
	100.00

Now this compound is analogous to a class of natural hydrated silicates called the zeolites, in so far as it is a highly basic silicate containing water. In one way, however, it differs from the zeolites, for it is most certainly a hydrated amorphous compound and does not assume or simulate a crystalline form. Johnson, in the well known and almost classic little work ''How Crops Feed,'' dedicates a chapter to the question ''Do Zeolitic Silicates, hydrated or otherwise, exist in the soil?'' and finally decides that they do, also that they are likely to be numerous and are undergoing alteration, as they are subjected to the influence

1 Comp. Johnson, How Crops Grow, p 343.

of one and another of the salts and substances that are brought in contact with them.

At this point the writer returns to his own inquiries. If indeed there exists in clays and rock powders a certain proportion of hydrated particles which are not crystalline in their nature, these must be classified as colloids. The question was how to prove this, or if absolute proof was impossible, to obtain all possible evidence. When silicic acid is prepared by carefully neutralizing a soluble alkaline silicate with hydrochloric acid, a colloid solution of silica acid is formed, and if the solution is concentrated, the silica separates as a jelly. If this jelly is allowed to dry rapidly in the air, it gradually assumes the condition of an apparently dry powder. This powder, however, is highly hydrated, and loses or gains water with changes in the moisture content of the atmosphere in which it stands. Heated gently up to a certain temperature it gradually loses water only to reabsorb it again on being allowed to cool in moist air. But once let the heat arise above a certain critical point, about 1000 C, and this absorptive power is gone once and for all. The colloid structure is destroyed, and only a dead amorphous powder remains. In short, silicic acid is a typical colloid.

In a former publication[1] the author has shown that plastic clays possess precisely the same power of dehydration and rehydration that silicic acid does.

It is interesting now to pursue the inquiry as to what is known about the structure of these substances which possess these peculiar absorptive properties. It appears from the work of Van Bemmelin[2] and others, that colloids possess a submicroscopic porous structure that enables them to absorb on account of capillarity or some allied force, not only water, but substances in solution, furthermore there seems to be evidence to show that this absorptive action is more or less selective, absorbing and holding certain substances and bases from solution so that they cannot thereafter be removed by any amount of washing and leaching. On this principle probably depends the entire action of lakes and mordants in dyeing, and accounts not only for the use of clays as "lakes," but also for their peculiar clarifying power as

1 loc. cit.
2 Zeit. Anorg. Chem. 5, 446, 13, 233.

in the well known uses of Fullers Earth, etc. It would seem that the micellian structure, to use a word of Nageli's, of these colloid particles appears to behave as though it were in a state of vacuo to water, and to certain substances in solution. Cameron[1] has observed that when a Morse osmotic pressure cell was buried "in a soil short of saturation, but yet in a fair condition for plant growth, the soil will draw water from the cell against a calculated osmotic pressure in the cell of 36 atmospheres, or about 500 pounds per sq. in." Such an important statement is worthy of an extended investigation. No one would venture to affirm that wetted sand or finely divided crystalline matter could exert such absorptive forces as these, and there is but one alternative, viz., to ascribe the phenomenon to the action of the micellian colloid structure. In fact, the evidence from every side is so overwhelming, that the wonder is that the problem has not been long ago recognized and studied from the standpoint of agricultural chemistry. If for instance the inquiry: "Do Zeolitic silicates, hydrated or otherwise, exist in the soil?" been extended to: "Do colloid modifications of the natural silicates and other known constituents of the soil exist?" the hint would have been given several years ago.

It appears then, that clays are to be considered as aggregations of particles which fall under three heads: (1) Non-plastic crystalline. (2) Non-plastic amorphous. (3) Plastic colloid. Experiment and observation have shown, however, that both plasticity and binding power will vary not only with the relative proportions of the three kinds of matter, but also with the particular character and activity of the sort of colloid matter that happens to be present. Undoubtedly the principal substance of which all good clays are composed is the hydrated silicate of aluminum or kaolin, and yet the variation in binding power and plasticity is very great. How then is this to be accounted for? The truth of the matter is that silica, alumina, the hydrated silicates and double silicates of aluminum, and many of the other metals are capable of existing in entirely non-plastic modifications. Furthermore, it is probable that even when the active modification is present, that its physical character will be influenced by substances that are absorbed in the micellian structure.

1 U. S. Dept. Agr. Bull. No. 22. Bureau of Soils.

With the means at hand of testing the binding power on relatively small amounts of material with the impact machine designed for testing road materials, it was possible to bring experimental evidence to bear on this interesting problem. Brucite and Bauxite are respectively the hydrated oxides of magnesium and aluminum. Chemically, these two materials are very similar, as can be seen by the formulae assigned to them by Dana, MgO, H_2O with 31% of water, and Al_2O_3, $2\,H_2O$ with 26.1% of water. There is, however, one characteristic difference between them. Brucite occurs in nature in a crystalline modification, whereas Bauxite invariably appears in a hydrated amorphous if not to say colloid form. Powdered Brucite proved to be without plasticity or binding power, whereas Bauxite was sufficiently plastic to permit of being moulded into forms, and had a fairly high binding power. Pure crystals of the zeolites, Analcite and Thomsonite, were obtained, containing respectively 8 and 14 percents of water. Both of these substances yielded powders which possessed low binding powers, and yet it is worthy of note that the zeolites have to a greater or less extent the same power of absorption that the colloids possess, that is to say, after being heated to 300° they very slowly regain the water they have lost when allowed to stand in the open air.

There is unfortunately no better test for plasticity than is given by the simple feel of a clay mixture, but a series of experiments was now planned to see if by mixing certain inorganic colloids with rock powders, clays, etc., the useful properties could be increased. A great number of colloid precipitates and substances were prepared in the laboratory, and washed as free as possible from the soluble products of the reactions by repeated decantations. The precipitates were then by means of a filter pump sucked as dry as was deemed necessary, and used in this condition for working up with the rock powders or clays to be tested. The first two substances were thus made and experimented with in this hydrated colloid form, were silicic acid and alumina. It was found that silicic acid increased the binding power and the shrinkage to a very high degree, but did not seem to increase the plasticity, while alumina seemed to increase the plasticity without giving any high degree of shrinkage or binding power. The next obvious step was to try the effect of mixtures of the two.

When sodium silicate (water glass) is added to a solution of alum or other salt of aluminum, a colloid precipitate is thrown down which does not appear to be of definite composition, and which we may express by x Al_2O_3 .y Si O_2 .z H_2O. Experiments made with this substance showed beyond doubt that both the plasticity and binding power could be increased by its use. The alumina can be wholly or in part replaced by other bases, such as ferrous and ferric iron, calcium, magnesium, chromium, etc. and thus the burning quality, as well as the plasticity and binding power modified. It is, however, only fair to say that raising the binding power by such means as these is a much easier operation than increasing the plasticity to the desired point, and in the opinion of the writer, the difficulty in the last case is on account of lack of density in the colloids. The amount of water they will hold even after they have assumed an appearance of being mechanically dry is enormous, sometimes as high as fifty per cent., and when in a pasty condition, they run as high as ninety percent. Undoubtedly in nature, clay masses have been subjected to great pressure as well as to the action of solutions containing organic matter, with which the colloid structure is actually stuffed and perhaps at the same time coagulated, thus increasing at the same time the density and the plasticity, and decreasing the shrinkage. It is assuredly true that this whole subject is worthy of further experiment and on a larger scale that has been heretofore possible.

A few words may be permitted here to show the special bearing of such problems as these on the study of road materials. Many rocks, when first crushed, have little value as binding material, and yet on ageing under the combined action of water and traffic, they finally consolidate and make excellent road surfaces. The most striking example of this is found in the so-called cherts of Alabama, which consist mainly of more or less decomposed beds of hydrated silica and silicious material. Every clay man knows that the useful qualities of clay can be developed by working and kneading with water, and it seems quite certain that the same thing is true of rock dust as it is gradually worn down under traffic. Not only are the colloids already present softened and rendered active by the free action of water, but undoubtedly new colloids are formed by the "kaolinization" of

the double silicates, as the alkaline and soluble constituents are leached out. It may indeed at the present time be impossible and impracticable to hasten these useful reactions in the open, but it is none the less important to understand the mechanism of them. Experiments to this end are at present being carried on in the laboratory. It is too early perhaps to give out any definite results, and yet some of the indications are interesting and may be briefly indicated. The "Kaolinization" of finely powdered feldspar, though a slow reaction, can be studied in the laboratory, as not only water but dilute solutions of both organic and inorganic substances attack feldspar and other double silicates, with removal and substitution of the alkaline bases and the development of new physical characteristics. It has been known for some time that in the treatment of alkaline double silicates, such as commonly occur in our crystalline rocks, they are more rapidly acted on by solutions of inorganic salts, if no common ion exists in the system. By this is meant that a potash feldspar should be more soluble in a solution of sodium chloride or ammonium nitrate than in a solution of potassium nitrate, or than in pure water. This is in accord with the modern theories of physical chemistry, and experiment proves it to be true, but from indications so far obtained, long digestion in ammonium nitrate solutions instead of increasing the binding power of rock dusts, decreases it, whereas digestion in pure water and in certain organic solutions has been found to notably increase it. Is it possible that solutions of soluble crystalline substances, *i. e.*, electrolytes, gradually attack and destroy the colloid structure? If this should prove to be true, it would be an important point of wide application. It would explain not only why certain mineral salts will clarify and settle turbid waters and solutions which carry clay and other sediments in colloid suspension and solution, but also in its bearing upon agriculture it would explain why the addition of one fertilizer to a soil will unlock other constituents not before available. Lastly, we need seek no further for the reason why kaolin from one bed has a good binding quality, while that from another has not; all will depend upon the past history of the deposit.

All this represents in part and but briefly some of the questions that are now under consideration in the Road Material

Laboratory of the Bureau of Chemistry, and more particularly in their bearings upon the problems that arise in the scientific study of road material. It would be presumption on the part of the writer to attempt to offer to this body any lengthy discussion upon the useful properties of clays, except in as much as the evidence so far collected seems to point the way to further consideration and experimentation.

To sum up, the following points have been presented for your consideration:

(1) That both plasticity and binding power are merely manifestations of a colloid modification of matter which exists in rocks and clays.

(2) That the activity of these useful qualities depends upon the characteristics of the special colloids that may be present as well as upon their past history, and the modifying effect upon them of saline and organic solutions.

(3) That absorptive qualities of clays, such as their ability to stick when touched with the tongue, and as exhibited by their occasional use as "lakes," clarifying agents, etc., is to be ascribed to the same cause.

In conclusion, it should be said that in presenting these points, the writer does not desire to minimise the importance of the effect of the shape and size of the grain on the useful qualities of clays. If the theory gains acceptance, which it will do if it is borne out by further experiment, although much that has not seemed clear hitherto will be explained, nevertheless the scientific study of clays will not be easier. The problem will be complicated by the necessity of considering not only two distinct kinds of matter with almost opposite properties, but also the peculiar modifying effect which they produce upon each other.

Discussion.

Professor Wheeler: I should like to inform Dr. Cushman that in working on the theory that the plasticity of clay is probably due to the fine plate structure, I found on taking the mineral brucite, the hydrate of magnesia, which has a lamillar or plate structure, I could take a crystal of it and by grinding get considerable tensile strength. With gypsum, another mineral with a coarsely laminated structure, by finely pulverizing it I got a high tensile strength or nearly to two hundred pounds to the square inch. I was not able to finely grind talc with much success, as talc is about as difficult to grind as mica, but succeeded in making it somewhat plastic, but brucite I succeeded in getting nearly as plastic as most clays, and gypsum more plastic than most clays, by merely fine grinding. (Gypsum is a hydrous sulphate of lime.)

Dr. Cushman: I tried brucite, too, and I tried many other minerals occurring in nature. Professor Wheeler's substance may not have been pure, even tho' occurring in crystals. Included in crystals may be actual clay matter. I was amazed to find how little impurity it required to give cementing power to my briquettes.

I do not think that Professor Wheeler's experiment by which he succeeded in getting this tensile strength out of brucite powder is worth as much as mine in failing to get it. His result is open to the criticism that he did not have pure brucite.

Professor Wheeler: Did you try selenite, or crystallized gypsum?

Dr. Cushman: No; but I tried mica, limonite and a great many hydrated silicates. . .

Regarding the question of alkalinity or acidity, which was brought in discussion of another paper this afternoon, I may say that the clays and soils from different parts of the country are found sometimes alkaline and sometimes acid, and there does not seem to be the slightest relation in this to binding power.

The bacteria question should be investigated; this problem would not be difficult.

One gentleman spoke of bacteria as "animals." I thought they were vegetable growths. It is known that they carry on reactions. But when it comes to the question of bacteria in a few hours producing such extraordinary qualities in clay, I find it dif-

ficult to believe. I have seen the binding power of rock dust increased to a marvelous extent by simple kneading. We take one portion, mix with water and make into briquettes at once; to the other half is added the same amount water and a boy kneads it on a board without stopping for an hour. The briquettes made without the kneading will break in sixteen blows of the kilogram hammer, while the portion which was kneaded for an hour will stand 190 blows of the same hammer. I refuse to believe that bacteria were at work there. (Laughter.)

Mr. Gates: Bacteria do not do it all, but I still believe there is something in the theory. The Chinese undoubtedly made use of fermentation in the treatment of their clays. We have had testimony here showing the benefits to clay from the action of bacteria, and I still believe that good things may be accomplished by inoculating clay and getting conditions proper for the growth of bacteria.

NOTE ON THE TENSILE STRENGTH OF RAW CLAYS*

BY

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The tensile strength of clays is a property which cannot fail to excite the interest of anyone who has had occasion to test many clays physically, and as is well known it varies greatly in different clays.

Thus, for example, a series of New Jersey clays recently tested showed average tensile strengths ranging from 20 lbs. per square inch up to 453 lbs. per square inch, and in another series from Texas, which the writer is at present studying, an even greater range of average tensile strengths has been obtained.

As far as the writer is aware, no explanation has been advanced for the cause of tensile strength, but some writers state that it is an index to the plasticity, which would indicate that the two properties are closely associated in their origin.

It is a well known fact that during the air-shrinkage of a clay the particles draw together into a more or less firm close mass, and that in many cases this air dried body is hard enough to show considerable strength, and to suggest that the grains must be tightly packed if not, perhaps, interlocked.

If the strength were influenced by the interlocking of the grains, the question arises what size or mixture of sizes would yield the greatest strength.

Investigations in soil physics have shown that when a mass of soil is composed of grains of equal size, these are not capable of compacting into a perfectly dense, tight mass, and that even with the closest arrangement there is still considerable pore space left, this being true of all equi-sized grains regardless of their diameter. With a mixture of grains, the pore space is reduced to a minimum because the variation in the size of the particles permits an exceedingly close adjustment or packing.

When any series of clays is tested it is evident that the coarse grained, highly sandy ones have a low tensile strength, and that

* Published by permission of the State Geologist of New Jersey.

many extremely fine grained ones, as far as the writer's experience goes, are also low in their tensile strength. Many clays, showing a high resistance to rupture, contain considerable grit, but still shrink to a hard and sometimes even dense body, indicating considerable percentage of fine particles.

In order to test the correctness of this view of relation of assorted sizes to tensile strength the writer selected five clays at random from the New Jersey series tested, the only precaution taken being to pick out samples ranging from high to low tensile strength. These five samples, together with their charters, were the following.

1. A soft, powdery, washed ball-clay from near Sayreville. It was plastic to the feel, with very little grit, and a tensile strength of under twenty lbs. per square inch.

2. Sample of Raritan clay from Cliffwood. A black, sandy, micaeous clay, with an average tensile strength of 105 lbs. per square inch.

3. A clay of the Cape May formation from along the river south of Millville. A gritty, plastic clay, with an average tensile strength of 289 lbs. per square inch.

4. Pleistocene brick-clay from near Somerville . This was also a gritty, plastic clay, but not as dense burning as the previous one. Its average tensile strengtth was 297 lbs. per square inch.

5. Clay from the Alloway formation from railroad cut north of Alloway. This was a very plastic, slightly gritty, dense, red-burning clay, with an average tensile strength of 453 lbs. per square inch.

Each of these clays was put through a mechanical analysis and separated into five classes of grains. The method of mechanical analysis used was that known as the centrifugal method, and is the one employed by the United States Bureau of Soils. It is quicker, easier to manipulate, and more accurate than the Schöne method. The clay samples were separated by this method into five sizes as follows:

Conventional Name	Diameters in millimeters
Clay substance	.005-.0001
Fine silt	.005-.01
Silt and fine sand	.01 -.25
Medium Sand	.25 -.5
Sand	.5 -.1

The percentage of these sizes in each of the five samples was as follows:

Conventional name	Percentages.				
	1	2	3	4	5
Clay substance.....	87.96	30.645	22.00	44.00	59.00
Fine silt.....	6.95	14.21	5.66	7.11	11.00
Silt and fine sand.....	3.00	5.585	26.55	24.35	14.70
Medium sand.....	1.00	6.400	11.45	7.80	3.50
Sand	.....	42.95	33.44	16.35	11.40
Totals	98.91	99.79	99.10	99.61	99.60
Average tensile strength	20	105	289	297	453

The above table, it seems to the writer, contains some rather suggestive facts.

Taking No. 1, whose tensile strength is the lowest, we find it has 87.96% of clay particles, and that the percentages of the other grain sizes is very small. Its tensile strength is low. In No. 2, whose tensile strength is only 105 lbs. per square inch, there is a large amount of sandy grains, viz. 42.95%.

Nos. 3, 4, and 5, it will be seen contain a mixture of the several sizes, with the clay particles forming the highest percentage in the case of 4 and 5.

From these it would seem that an excessive amount of clay particles, or large percentage of sand grains weakens the strength of the air-dried clay.

If the theory of interlocking particles is true then it should be possible to make a mixture of two clays whose tensile strength is higher than that of either of the clays alone, or vice versa. While the writer did not have the opportunity of making experiments to prove this point, some results were obtained in the course of the physical work on the New Jersey clays, that have an important bearing on it.

Of several clays tested from the Asbury clay formation near Asbury, one was a slightly gritty, black clay with an average tensile strength of 182 lbs. per square inch. The other was a plastic loam, whose average tensile strength was 137 lbs. per square inch. A mixture of the two in equal proportions, however, had an average strength of 258 lbs. per square inch. Another clay from a different formation had an average tensile strength of 108 lbs. per square inch, while a mixture of equal parts of this clay and

sand, showed a tensile strength of but sixty-five lbs. per square inch.

It may seem doubtful whether mere interlocking alone is sufficient to account for the tenacity of the clay, and whether or not the organic substances included under the general term of *colloids,* and which are no doubt present in many clays, do not exert some cementing action. Suggestions regarding the effect of these must be looked on as speculations until proven. In fact the observations given above are not to be considered as final conclusions, but are presented with the hope that they may bring forth some discussion which will aid in clearing up the cause of tensile strength.

There is another point in connection with tensile strength to which attention should be called, and that is the use of the tensile strength as a measure of plasticity. This seems to the writer to be incorrect, and no doubt many others have noticed this also. While it is true that most lean clays have a low tensile strength, and many clays of high plasticity have a high tensile strenth, still there are many sandy clays of low or moderate plasticity whose tensile strength is high. This is true, for example, of some of the clay marl of New Jersey, and several excellent examples of it have been found in the Texas clays.

Many highly plastic clays show a low tensile strength, but this is often due to the formation of small cracks in drying which cause the briquette to break before its ultimate strength is reached.

Professor Orton in two very interesting papers presented before the society* came to the conclusion that the tensile strength of a clay is increased with a decrease in the diameter of the nonplastic ingredients, and fine grained clays will, other things being equal, possess the greatest tensile strength. It is somewhat difficult to compare the tests here given with those made by Professor Orton, for in his experiments only one size of nonplastic grains was mixed with the clay particles, and then in equal parts. Making comparison as far as possible it would appear that in raw clay an excess of fine grains decreases the strength.

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* Trans. Amer. Ceram. Soc. Vol. II, p. 100; Vol. III, p. 198

DISCUSSION.

Professor Wheeler: As the Secretary overlooked me in sending out the copies of Mr. Acheson's paper, the paper on Egyptianized clay is new to me, and I wish to carefully read Dr. Cushman's paper before discussing it. The paper of Dr. Ries presents data that will bear further study. While the evidence furnished by Dr. Cushman indicates that there may be several causes of plasticity, (and his colloidal hypothesis is deserving of careful consideration) it is at least premature to abandon our former ideas as to the cause of plasticity in clays.

Before discussing plasticity, I desire to bring out one feature shown in the analyses presented by Dr. Ries, viz.: The range of tensile strength from 20 to 453 pounds to the square inch, obtained by simply mixing the clay with water and allowing it to dry. The stronger clays have a tensile strength equal to many Portland cements, and far superior to the average natural-rock cements. The figures given by Dr. Ries are very valuable, in the light of our former theories, because the weakest clay has the most clay substance, and the next richest in clay substance has the greatest strength. Another clay with quite a considerable portion of foreign matter has a marked plasticity.

In correlating plasticity with tensile strength, I have drawn the line at 100 pounds to the square inch as being a fairly plastic clay; such a clay 99 out of 100 potters would term a plastic clay. If it has less strength, they would call it a lean clay, and, when more, a decidedly fat or very plastic clay.

The clays cited by Dr. Ries bring out the fact very sharply and clearly that the plasticity of a clay is mainly a factor of the physical condition of the clay particles, rather than the percentage of the clay substance. If the particles are in a favorable condition, a small percentage of clay substance will give the mass decided plasticity and strength. If on the contrary the particles are not in this favorable condition, almost pure clay substance will give but little plasticity or strength. Now under the microscope I have found that when the crystals of the clay were coarsely lamellar, the clay was but little more plastic than so much sand; if the crystals are broken up into thinner plates we get a moderate plasticity, and when they are broken up into very thin plates, even tho the clay

be contaminated with a large quantity of sand and foreign matter, the clay is very plastic.

While I am responsible for advocating the tensile strength method as the most satisfactory way of measuring the plasticity of clays, I tried to make it clear that it was a tentative and not altogether satisfactory method. For I have found certain clays in Missouri, of the residual or surface type used for red brick, which tho heavily diluted with sand, gave remarkably high tensile strength, tho the plasticity, as judged by the feel, was much less pronounced. This great strength I explain by the clay substance, tho present in moderate to small amounts, being in the condition of extremely thin plates, interlocking and weaving the mass into a strong body on drying, tho the large percentage of sand gives it a more moderate degree of plasticity, as judged by the feel, when wet. Unquestionably, a softening of these thin plates by chemical action, whether secured with tannin or by exposure to the elements, would make these plates more susceptible for interlocking, and, hence, increase the strength, by enabling them to bend more readily over and around the sand particles.

Dr. Cushman's hypothesis is worthy of careful study and investigation, but I think much must be done before we can accept it as a satisfactory theory for the plasticity of clays.

Dr. Cushman: I presented it as a theory only; if experiment does not bear it out, then I have no desire that it shall live. When it comes to an explanation of the figures given in Dr. Ries' paper, they are just as well explained by my theory as any other. I pointed out that everything depended on the activity of whatever colloids might be present.

Tensile strength as a measure of plasticity is open to severe criticism. Take the instance of a piece of broken crockery with the broken part cemented together with a little casein glue, as one sees on the streets with heavy weights attached. Here we have tremendous tensile strength, but it does not show how it would stand cross breaking strains. The clay which shows a tensile strength of 453 pounds to the square inch would not work well if put to the same uses as a Portland cement. Of a Portland cement you could build a floor and drive wagons over it, but the clay product would not wear long under such conditions. Tensile strength does not tell much about the qualities of a clay.

Prof. Charles F. Binns: I think it is agreed that tensile strength is not satisfactory for plasticity, but there is another fact which must be taken into consideration in connection with these tables—this is a mechanical analysis, not a chemical one. Clay Number One is entirely in a fine state of division, over ninety per cent. of it being below .025 of a millimeter. There is nothing to show that fifty per cent. of this might not be fine grained quartz, and we should not necessarily expect great plasticity or tensile strength.

Subsequent Note by the Author.

While it is quite true, as Professor Wheeler states, that the tensile strength shown by some of my experiments was equal to many Portland cements, still the strength remains only when the clay is in a thoroughly dry condition. It seems to me that Professor Wheeler is certainly right in saying that the condition of the particles exerts an important influence, that is, if the clay particles are bunched together or flocculated instead of being in a puddled condition they would no doubt exert less binding influences on the mass.

In reply to Professor Binn's remark, I would say that clay No. 1 that shows such a high percentage of clay substance has by rational analysis over 98% of clay substance. It is a washed ball clay from New Jersey and, therefore, there is no possibility of 50% of this clay being fine grained quartz as Professor Binns suggests.

INFLUENCE OF MAGNESIA ON CLAY.

BY

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As has been pointed out by Maeckler[1] and confirmed by Mr. Hottinger[2], magnesia serves to widen the distance between the vitrifying and melting points of clays containing lime or more active fluxes and to reduce porosity of such bodies at a given temperature. A broader claim for the value of magnesia does not seem justifiable from the data so far obtained and there are some points in connection with the use and value of this material which have not been touched upon at all.

There is no doubt that magnesia is a desirable *substitute* for lime, entirely or in part, in low fire bodies where it is desired to have a greater margin between the vitrifying point and the fusing point than exists with lime alone. Just how quickly lime exerts its fluxing influence and how magnesia bodies slowly travel towards fusion through the same increase of temperature is nicely shown in the shale experiments carried out by Mr. Hottinger. In the porcelain experiments, however, the temperature was not carried to the critical point for this class of ware. Whatever effect magnesia may have on a *porous* porcelain body, does not convince one of its value in a *non-absorptive, vitrified* body. If these experiments had been broadened by carrying the bodies to vitrification, and determining the different densities, the results would have been more conclusive as to the value of magnesia in giving dense bodies which remain true to shape under vitrifying heat.

Lime, as has been repeatedly demonstrated, invites distortion of ware under a vitrifying fire, and its entire or partial replacement by magnesia serves to correct this fault. As an example of this, Maeckler cites the case of the compact structure and sharp angles of the Hungarian Ceramite blocks, which Tetmajer found

1. Thonindustrie-Zeitung 26 (54) 705-709. 2. Trans. Am. Cer. Soc. 1903, 5, 130-133.

to contain 4.94% MgO and 18.15% CaO. Or, in a shale where the fluxes are mainly iron and the alkalies, magnesia may serve to correct abrupt changes from vitrification to fusion. But magnesia added to a porcelain body with potash as its sole RO element, i. e., a purely feldspathic porcelain, may detract from its qualities in several ways. The following is a series of bodies, starting with a feldspathic porcelain recommended by Hegeman*, and introducing lime and magnesia separately and together. This was done by molecular replacement with the exception of No. 31, which is practically 95% porcelain body No. 26 and 5% magnesia.

No.	Formulae.					Ingredients.					Per Cent. Shr'k age.	Specific Gravity.
	K_2O	CaO	MgO	Al_2O_3	SiO_2	Spar	Clay	Flint	Lime	Magnesia		
26	0.245	.....	.....	1.00	4.00	35.00	50.00	15.00	....	....	14.5	2.38
27	0.1632	0.0816	.....	1.00	4.00	23.20	54.82	20.00	2.08	....	15.2	2.35
28	0.1632	.....	0.0816	1 00	4.00	23.50	55.52	20.25	....	0.84	17.5	2.40
29	0.0816	0.0816	0.0816	1.00	4.00	11 62	60.32	25.05	2.08	0.84	17.7	2.33
30	0.0816	.....	0.1632	1.00	4.00	11.77	61.09	25.37	....	1.69	17.1	2.33
31	0.243	.....	0.507	1.00	3.95	32.60	47.80	14.48	....	4.94	17.2	2.31

Burned to cone No. 11, numbers 26, 27, 28 and 31 were fine, hard, white porcelains, thoroughly well vitrified. Numbers 29 and 30 were hard and white but not thoroughly vitrified. This is due to the too great depression of the feldspar, resulting from adding MgO and CaO at the expense of K_2O. It will be noted that the magnesia bodies have excessive shrinkage, but, in point of density, No. 28, containing .1 equivalent MgO, is the best of the series with No. 26 a close second. This would tend to bear out the statement as to the value of magnesia in securing hard, dense bodies. However, in other trials, pure feldspathic porcelains were obtained (very close in composition to No. 26) with a specific gravity of 2.43, thus surpassing the magnesia body. The drop in specific gravity of No. 26 on the addition of 5% of magnesia is also significant.

In remarking upon the paper Prof. Orton says, "One of the chief points of value is the demonstration of the fact that magnesite as a flux will enable us to get vitrification at actually lower

temperatures." As yet this statement hardly seems warranted. With the exception of the shale, none of the bodies experimented upon by Mr. Hottinger were carried to the vitrifying stage and compared. The shale, with and without magnesia vitrified apparently at about the same point. In the experiments with the porcelain mixture, the nearest approach to vitrification is in trial B-6, which reached an absorption of 6% at cone No. 5, while the porcelain body without addition had an absorption of 14.4% at the same heat. While to all appearances the magnesia body is approaching vitrification faster than the unadulterated porcelain body, we cannot say how much sooner it would become vitrified. The experiments were unfortunately stopped just short of clinching the point. In Maeckler's experiment with kaolin, as noted by Mr. Hottinger, the *pure kaolin is approaching vitrification faster than either of the magnesite mixtures.* Trial L, with 21 parts of magnesite, actually *increased* in porosity from cone 1 to cone 5, and under the same change of temperature trial M dropped in porosity 15%, whereas the kaolin dropped in porosity 29%.

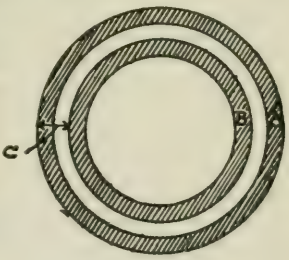
In the case of the shale I think, after all, the effect of the magnesia is not surprising and the cause is to be looked for not far from the old statement of Seger's as to the fluxing power of magnesia. Magnesia is a harder flux than lime and if substituted for lime in a glaze or in a vitrified body it stiffens the mixture. This magnesite, which is highly refractory, and added it to 100 parts of has often been verified by the writer. If you took 21 parts of magnesite, which is highly refractory, and added to it 100 parts of shale, as Mr. Hottinger did, would you not expect the melting point of the shale to be raised? At the same time, vitrification would *commence* very close to its original point amongst the shale particles. But to incorporate the more refractory magnesite particles would require additional temperature and time. We thus have not only raised the melting point of the shale but have broadened the range of vitrification. There is very little difference in trial C-4 of Mr. Hottinger's experiment and the pure shale trial under cone 1 heat. C-4 stands up longer, however, under increased heat, simply because it contains particles of a hard base which are entering into silicate formation slowly. If, instead of magnesia we had added to the shale the same amount of some other refractory base, as chromic oxide, it is very probable

we should have obtained results similar to those shown by magnesia.

Turning to the purely practical side of the subject we find several objections to the use of both lime and magnesia in a hard porcelain body.

Maeckler states that the property of shape retention may be imparted by the addition of a small quantity of magnesia and later cites the case of an insulating cap which was found to contain 31% MgO. Such a percentage of magnesia as this would certainly interfere seriously with the pressing of low potential electrical porcelain which is made on the ordinary screw tile presses. In this class of ware there are many intricate shapes and the ingredients of the body must be kept carefully proportioned to meet the requirements of the presses. A small percentage of lime or magnesia (as low as 5%) added to a feldspathic porcelain immediately "shortens" the mixture and, while it would still be possible, perhaps, to press some shapes successfully, intricate pieces would work poorly and break easily.

Another disadvantage of magnesia is the increased shrinkage it gives to the body of which it forms a part. The greater the shrinkage in pieces of certain shapes, the greater the tendency to warp. Especially in thin-walled, cylindrical pieces it is desirable to have a small shrinkage. Such pieces, in shrinking and drawing over the rough sagger bottom on which they rest, very easily have their circular section distorted at the base. Letting the section A represent the section of such a piece resting on the sagger bottom in firing, and B the final size of the same section left by the fire, the greater the distance C, the greater the tendency of parts of the circular section to be held back mechanically behind other parts in shrinking, with consequent distortion. Magnesia undoubtedly aggravates this trouble because of its influence on shrinkage.



A still further disadvantage of magnesia is its tendency to make porcelain stick under a vitrifying fire. A large part of small ware is "stacked" in a vitrifying biscuit fire and the pieces, of

course, must not adhere when in contact. Porcelain containing magnesia will stick more or less.

In conclusion, what I wish to emphasize is the fact that the action of magnesia will depend a great deal upon the character of the body or glaze in which it is used. In bodies containing a number of active fluxes and which vitrify at a low temperature magnesia has a very noticeable effect upon the melting point and the temperature range of the vitrifying stage. As the number and character of the bases change in going towards high fire products, the influence of magnesia lessens considerably. It is perfectly possible to make a feldspathic porcelain which at a given temperature becomes thoroughly vitrified and non-absorbent, hard and dense, has a moderate shrinkage and can be burned into thin-walled pieces which retain their shape splendidly. Magnesia, introduced into such a body not only fails to give any marked improvement, but, as seen from the few foregoing tests (which were repeated a number of times), increases shrinkage, lowers the density, makes a "short" mixture to work, and invites sticking under fire.

Furthermore, as far as all records show, the use of magnesia has never been extensively resorted to in the fine, dainty, fragile chinas and porcelains of France, England, China and Japan. This, of course, does not prove that magnesia would not be of any value in such compositions, but the fact that such ware has been and is made successfully without it tends to limit its value to the fact that possibly these delicate shapes can be put through the kilns with less care with than without magnesia. This is a questionable advantage, especially in the face of the disadvantages before pointed out.

DISCUSSION.

Mr. A. F. Hottinger: I have not carried my experiments much further since my paper last year, so I cannot say much. I did find in a single experiment which I made, the excessive shrinkage which Mr. Barringer mentions. It was a Seger porcelain body using magnesia, and I was surprised at the great shrinkage.

Mr. Barringer: I do not think the shrinkage is surprising, when we have in mind magnesia crucibles which have already been in the fire. It seems no matter to what heat they have been burned, they will continue to shrink if further heated. Further, this work on magnesia in clay mixtures, which has come up several times,

tends to show that the law of complex bases is limited. It is generally thought that the more bases in a body, the more fusible, but this does not show it. In some cases the fusibility increases and in some decreases.

Professor Charles F. Binns: I want to ask whether there has been any notice taken of color. Mr. Barringer spoke of "white" color. In any experiments which I made with magnesia I almost always found it destructive to the color of a porcelain body.

Mr. Barringer: As far as color is concerned, I noticed no difference whatever. They were all nice, white, hard porcelains. The only differences noted are those mentioned in my paper, viz., shrinkage and specific gravity.

Mr. S. G. Burt: I will ask Mr. Barringer whether, in speaking of magnesia crucibles, he is speaking of pure magnesia or a mixture?

Mr. Barringer: That I cannot say, except they were sold for magnesia crucibles, and I presume they were very high in magnesia.

Mr. Burt: They were not pure?

Mr. Barringer: The only difference we noticed was in pieces of the shape indicated in the sketch, which showed in the greater shrinkage and drawing on the sagger bottom, causing distortion. In the solid pieces, like cut-outs, switch bases, etc., the effect was not noticeable, as far as distortion was concerned. Both were distorted slightly more than the feldspathic body.

Professor Binns: I understood Mr. Barringer to say that the action of lime and magnesia is contrary in that respect? We know that lime brings the points of vitrification and viscosity close together, and I understood Mr. Barringer to say that magnesia had the contrary effect?

Mr. Barringer: What I said on that matter was in referring to shales. As I said in my paper, there certainly is a difference in the action of magnesia in high fired and low fired bodies. The fluxing action is more noticeable in low fired than in high fired bodies. As far as appearance went, these porcelains looked exactly alike. The only difference was found by measure in the shrinkage and specific gravity. But the same quantity of magnesia added to a shale and to a porcelain body burned to that shale's temperature, would certainly give different effects. I think it would be more

noticeable in the shale than in the porcelain body. That was the conclusion drawn from Mr. Hottinger's paper, that magnesia was a good thing to add, assisting vitrification and fusing points, bringing them close together.

Mr. Burt: I would like to ask Mr. Barringer whether he can give the temperature to which these various bodies were fired. It seems evident that vitrification did not occur at anything like the same degree of heat, and the actual temperature becomes an interesting point.

Mr. Barringer: These porcelain samples were made up and all fired at the same time, burned in the same sagger, and the experiment repeated a half dozen times. They were burned on an average to heat of cone twelve, and as far as I could see, the pieces were as thoroughly vitrified as the regular line of porcelain. I did not run any absorption tests. That would be the better way to show it. Ink was not absorbed on any of these tests.

Mr. Burt: You did not find any variation in fusibility?

Mr. Barringer: No difference, so far as vitrification is concerned.

Prof. Edward Orton, Jr.: This discussion has brought out one point, which I will not attempt to explain. Maeckler's original paper was based largely on researches made on roofing tile clays, which vitrify at very low heats; Mr. Hottinger's conclusions, to a considerable extent, were derived from experiments on shale bodies, which also vitrify at low heats. If there is a difference in the real role played by magnesia in the two classes of bodies, high-fired porcelain and low-fired bodies in which iron is a prominent constituent, it is likely that iron is largely to blame. Bleininger has done work along that line in Portland cements, and while cements are not pottery bodies, the principle involved may help us.

Mr. A. V. Bleininger: Ferric oxide plays an exceedingly important role in bringing about vitrification in cements. If we were to make a portland cement of pure kaolin, whiting, and flint, the cement could not be burned in any commercial kiln. The temperature would be beyond reach commercially. A small per cent. of ferric oxide lowers the temperature, and brings about combination. In this way, we obtain a portland cement containing about seven per cent. of ferric oxide. Seven per cent. is about the commercial

limit. The ferric oxide plays an exceedingly important role in bringing about vitrification.

Prof. Orton: With that explanation, we can form a sort of working hypothesis to reconcile these conflicting views. Mr. Barringer is reasoning largely from experiments made with white bodies fired at cone twelve, a compound of china and ball clays, flint and spar, and he has added magnesia and calcium oxides as subsidiary fluxes; the experiments of Maeckler and Hottinger were along the line of low temperature bodies, in which iron was an important ingredient. May not the proportion of iron be the critical thing in determining whether the magnesia acts well at low or high temperatures? In view of the action of iron in cement mixtures, as found by Mr. Bleininger, where the problem is to develop combination between sand and clay with large quantities of lime and magnesia, may we not expect a similar set of conditions in clays, where sand and clay are to be combined with smaller quanties of lime and magnesia at lower temperatures.

Mr. Barringer: There are certainly some confusing phenomena which need to be worked out. In slags, Howe has found that with a given acidity uni-and bi-silicates have the melting point increased by the use of magnesia, while tri-silicates have it lowered, but we do not know exactly why this should be.

THE FUSING POINTS OF SEGER CONES EXPRESSED IN DEGREES.

BY

S. Geijsbeek, St. Louis, Mo.

In recent papers and investigations we find there is quite a difference in opinion in regard to the melting point of Seger cones as compared with the measurement in degrees of heat as expressed by the Le Chatelier Pyrometer.

Wheeler[1] speaks of the irregularity of the melting of Seger cones, and gives as his views that the absolute melting point of Seger cones cannot be determined within 100 degrees Fahrenheit.

Orton[2] has noted that Cremer cone 02 fused at 1155 degrees C. or 35 degrees C above its temperature, and that Cremer cone 010 fused at 1055 degrees Centigrade or 100 degrees above its schedule temperature.

Hofman[3] states that by using Seger cones in order to be scientifically correct, you must leave out degrees of heat and give your results as occurring at Seger cone so and so. Degrees centigrade are only used to bring the results in comparison with pyrometers.

Purdy[4] cites a case where in a second burn the cones come down 15 degrees centigrade earlier than they did in the first burn according to the readings of the pyrometer.

Dr. Zimmer[5] found 25-30 degrees centigrade difference in readings according to the pyrometer between a slow and quick fire.

These statements indicate that there is room for doubt as to the value of either the cones or the pyrometer as compared with each other.

(1) Missouri Geological Survey, Vol. XI, page No. 140.
(2) Trans. American Ceramic Society, Vol. V, page Nos. 321-330.
(3) " " " " Vol. V, page No. 226.
(4) " " " " Vol. V, page No. 149.
(5) " " " " Vol. I, page No. 23.

It is to be regretted that two methods which have proven so highly satisfactory for testing high temperatures, especially in connection with our ceramic work, should be subjected to criticism as cited above.

We can trace this matter back to the early contributions in English, which were more or less translations of the original articles on cones, and their comparison with degrees of heat as expressed by the Le Chatelier pyrometer. While it was not the idea of the investigators at that time to compare cones directly with dedegrees of heat, their translated statements were not worded strong enough to prevent the public from taking it for granted that cones should melt at exact temperatures, nor have the more recent statements improved the situation.

Referring back to the original articles, Seger cones were only just introduced. They were used mostly for experimental purposes, quick heat and their results. The Le Chatelier pyrometer was also at that time an instrument of recent creation, and it was only natural that both should be used for comparison in the light of experimental purposes.

However, today, we find different conditions. Cones have gone through the experimental stage, and so has the Le Chatelier pyrometer. Both are here to stay, with this difference, that the former is an indicator of *approximate* temperature values, while the latter gives the *exact* value of heat temperatures.

As we are using cones, it is only natural that we should like to know at what temperature they melt, even approximately, and the tables now in use are the same ones as used in the early part of the introduction of both cones and pyrometer. They give us the value of quick heats and their results, but leave us entirely in the dark as to the regular conditions in use in practical Ceramics.

Any table or statement, therefore, giving the approximate degrees of heat at which Seger cones will melt, without stating the conditions as to rate of firing, is subject to serious suspicion of its merits, and is not a document in which we can place any reliance.

To illustrate the point, I will give the results of some investigations along this line. I have tested Seger cones under two different conditions: (1) quick burning and (2) slow burning

conditions, yet still keeping within the range of practical and not experimental Ceramics.

The kilns in which these tests were made were muffle kilns. They were fired without paying any attention either to Seger cones or to the pyrometer, and were finished according to the judgment of the superintendent of the works, by trial pieces coated with colored and Albany slips.

The pyrometer used was the Heraeus Le Chatelier pyrometer and was repeatedly tested against gold and silver as to its correct reading for these melting points. The Seger cones used were the standard pyrometric cones made at Columbus, O., by Prof. Edward Orton, Jr.

The Seger cones were put in the kiln in such a position that the end of the pyrometer tube containing the couple nearly touched the middle of the height of the Seger cones.

The following results were obtained, and are herewith tabulated.

Cone Number.	Melting Temperature in Degrees Centigrade.		
	Official Temp. published by Thon. Ind. Zeitung	As shown in a short burn of 24 hours duration.	As shown in a long burn of five days duration.
1	1150	1110	1035
2	1170	1130	1050
3	1190	1155	1070
4	1210	1170	1095
5	1230	1190	1110
6	1250	1205	1130
7	1270	1230	1155

It will be seen at a glance that there is a difference in the degrees of heat required to melt a cone under different conditions. It appeals to me as being advisable, in order to overcome erroneous ideas as to the actual melting point of Seger cones, to correct the tables now in use and confirm the temperatures with the conditions under which Seger cones are used.

A desire to have these tables revised has been expressed formerly by Dr. Zimmer[1]; he stated that he hoped that the temperature scale of Seger cones would be corrected according to our large and slow burning biscuit kilns.

(1) Transactions American Ceramic Society Vol. 1, page 23.

Most tests made in regard to heat determinations, and specially those mentioned in our transactions, are usually made in a short time, 4 to 5 hours. They hardly come within the range of practical Ceramics, and, no doubt, the difference between an actual factory burn and a laboratory test, is generally appreciated by those who conduct such experiments.

Purdy[1] says: While these glazes, thus tabulated, fused considerably under cone 2, and would give good glossy glazes at cone 2 or lower, when burnt in as short a period of time as this test was, they would require cone 5-7 in the longer burns of the regular stoneware operations. The test of which he speaks was made in about seven hours.

It takes the same conditions of firing to produce the same results, and while cones will slowly fuse or "soak down," it is not always necessary to have the same heat. In my tests above tabulated, which run over a period of about one year, I have found that the melting point of Seger cones in the long duration of firing will vary about 10 degrees centigrade.

It seems, however, that in shorter and quicker fire the variations run far higher. Orton[2] gives in his paper, "An Easily Fusible Glass Without Lead or Boracic Acid," the melting points of Cremer cone 010 at resp. 910, 925, 945 and 1050 degrees centigrade. In the same paper[3], he also shows that he obtained for three different glass mixtures burnt at two different times the following actual degrees of heat as read by the Le Chatelier pyrometer.

	First Burn.	Second Burn.
Glass mixtures No. I-X.....	1125 deg. C.	1170 deg. C.
Glass mixtures No. I-X.....	1125 deg. C.	1170 deg. C.
Glass mixtures No. I-V.....	1125 deg. C.	1192 deg. C.
Glass mixtures No. I-T.....	1150 deg. C.	1210 deg. C.

It must be conceded that all these experiments prove that the same mixtures have different fusion points under conditions, which while we *believe that* they are the same, they are in fact different.

Orton started his new experiments for the lower series of cones by the fact that these cones did not act regular. His very

(1) Transactions American Ceramic Society Vol. V, page 160.
(2) " " " " Vol. V, page 305.
(3) " " " " Vol. V, page 316.

experiments prove that other mixtures than cones fuse at different temperatures under presumably the same conditions.

The fact, however, which the writer wants to bring to closer attention is that while it has been proven beyond doubt that most ceramic mixtures (cones included) fuse irregularly, some investigators go so far as to attribute these defects to the Le Chatelier pyrometer.

Purdy[1] attributes the difference in actual readings of degrees of heat between two burns to the pyrometer couple. The same was used in one burn between reading times for other purposes, and for that reason he states it will suffer sufficiently by such treatment to differentiate the readings.

Purdy does not explain the reason why he thinks that the pyrometer couple should suffer by such actions. I have never so far observed any variation in the temperature readings by just such changes as Purdy described. Inasmuch as the readings with the Le Chatelier pyrometer are instantaneous after the protection tubes are well heated, I cannot see where a difference should take place.

Orton[2] does not think that the pyrometer readings he obtained in the experiments already cited above are the absolute melting points of his mixtures, and says: "These readings must not be considered as *having a close* comparative value." But at the same time he notes the fact that the readings were used to indicate the relative temperature intervals between fusions.

It seems strange that Orton should not accept these readings as absolute melting points of his mixtures, in view of the fact that he has no other method of determining the same, except cones, whose absolute melting points can not be expressed in degrees of heat with certainty. He has not faith in the total degrees of heat registered by the Le Chatelier pyrometer, but puts enough faith in a few degrees to indicate the relative fusion temperatures. There must be something lacking about the stability of the fusion-points of cones if the Le Chatelier pyrometer must come to their rescue in order to make the experiments valuable.

That ceramic mixtures like cones are quicker subjected to flashing than the pyrometer, and that the latter gives a more constant

(1) Transactions American Ceramic Society Vol. V, page 148.
(2) " " " " Vol. V, page 317.
(3) " " " " Vol. V, page 313.

reading, Orton[3] has noted several times. In one place he speaks of it as follows: "In the lower muffle, two mixtures were both carried down and one partly down by a flame striking them for a few minutes after freshly baiting the fire. The pyrometer registered only 560 degrees centigrade. The temperature of the flame, which carried the cone down, was not indicated by the pyrometer. After stopping the flame and bringing the heat up more uniformly, no change in the glass cones was produced until Cremer cone 05 started. The cone which had fused down partly now was melted down completely."

The difference in actual temperature must have been some 500 degrees centigrade, which brought this glass cone down to complete fusion.

In citing another case Orton[4] states that a cone bent to a perfect semi-circle early in the firing, and stood in that form for nearly three and a half hours before fusing down, while the pyrometer rose from 600 to 880 degrees centigrade.

When a clayworker burns his five day kiln at Seger cone 1, or approximately, 1150 degrees centigrade, according to the tables now in use, he would be surprised if he knew that the actual heat is only 1035 degrees centigrade as shown by my observations. If he had burnt his kiln to 1150 degrees centigrade by the pyrometer, cording to the old table for a Seger cone 1 heat, his kiln would have attained a heat close to Seger cone 7 by my new table, and it would be only natural that he would lose faith in both Seger cones and pyrometer, and that he would go back to old trial pieces as being better than all these new improvements of modern Ceramics.

In presenting these facts, I do not have in mind to advocate Seger cones or to criticise the Le Chatelier Pyrometer, as I know both methods have their valuable points, but I have in mind one fact and that is that we should stop long enough to consider these data, and see if it would not be advisable to leave the old narrow trail, and grade a new roadway by accepting the old table of cone temperatures for experimental purposes *only*, and establishing a new one which will bring us closer to our daily work in practical Ceramics.

(1) Transaction American Ceramic Society Vol. V, page 423.

DISCUSSION.

Professor Edward Orton, Jr.: I have had no opportunity to see this paper in advance, and, therefore, have prepared no response. The paper brings up some points, which we have discussed before and which it seems may be stated now again. They appear to need stating perennially. I happen to have here a copy of Watkins' paper recently read before the English Ceramic Society on the "Method of Measuring Heat by the Contraction of Clays," in which he quotes from Seger's work the following paragraph:

"The melting points of the lower numbers of the series have been expressed in degrees of the thermometric scale, but I have been obliged to make many hypothetical assumptions. I have assumed that the series with cone No. 1 begins at 1150° C, and reaches the highest temperature assumed at 1700° C; and that furthermore all cones represent equal intervals of fusibility. Thus I have interpolated, to fill up the intermediate terms of a series, the degrees. I must say that I have reluctantly done so, in obedience to pressure from manufacturers and that I must always make reservations in regard to these thermometric degrees. But for the highest numbers I do not venture to follow the same plan, for lack of tangible data. Once accustomed to designate temperatures by cone numbers, one will find them adequate even if they represent an expression differing from the customary notation. For instance, let it be stated that a clay comes up to cone No. —, and a definite fusibility is thus expressed and the same point can always be found in the future. It will not be necessary to add degrees impracticable to directly verify."

This is the statement of Dr. Seger on this point. He did not bring the question of temperatures as bearing on the service these cones were to render. He was only induced to connect his cones with fixed temperatures by the pressure of friends and business associates who were looking after the commercial side. It was done to make sales easier My own experience in the manufacture and sale of these cones has amply demonstrated the wisdom of Dr. Seger's point of view. It is unfortunate that the fusing temperature should ever have been made so prominent in the use of the cones. It has always seemed so to me. I do not know that it seems any different now.

When Mr. Geijbeek first began to write his results on the board, I confess to some little trepidation, because I did not know what my cones might have done, but I feel that they have shown very fairly well relative temperature conditions. If there had been more marked inequalities, I would have felt some mortification, perhaps, but as it is it seems that the series is surprisingly good.

These temperatures were *assumed* in the beginning; they were adopted against Dr. Seger's better judgment. As to the perpetuation of that idea of a definite temperature at which cones melt, I think Mr. Geijsbeek has furnished the best possible argument against it. The amount of sulphuric acid in the coal and various factors come into the question. I submit it is not worth while to attempt to perpetuate the temperature idea with these cones. In all my letters or correspondence on the subject of Seger cones, I have studiously attempted to do away with the use of temperatures. Upon request for this information, I tell the applicant where the cone is supposed to melt in the centigrade scale, sending him typewritten or carbon copies of the supposed melting point temperatures. I do not care enough about the use of temperatures even to have it printed. I say, "After you get used to dealing with cones you will forget all about temperatures, and deal with cone numbers instead, which is the correct basis.'

What I said in Volume V on the melting points of certain glass amounts to this: The glasses were melted at various times through several months; the temperature of the atmosphere in the kiln house and around it materially differed from one time to another. It is well known to those dealing with the Le Chatelier pyrometer, that the current, or rather the voltage generated by the thermocouple, is proportional to the *difference* in temperature between the junction of the couple and its free ends. If both ends of the couple were of equal temperature no current would be generated. The temperature is estimated by measuring the intensity or voltage of the current generated. Hence, if the couple is in a hot kiln and the free ends are out in the open air, the reading will vary by whatever variation in the outside atmospheric temperature may exist from day to day. From a warm day in summer to a cold day in winter this would be very considerable.

If we want to produce *standard* readings, the outside ends should be placed in ice-water, thus securing a constant starting

point. For my purpose, I did not deem it of importance to do that. I only used the pyrometer with the idea that it would give a regular series of differences—that the series of any *one one burn* would be consistent with themselves. Mr. Geijsbeek, I think, will now understand what I said in the paragraphs quoted. If I had tried to get the finest work possible out of the instrument I could have gotten readings of comparative constancy.

Professor Wheeler: Was raw material used in both cases?

Professor Orton: No; the mixtures were previously melted to a perfectly clear, glassy condition, cooled, sorted, pulverized and made into cones. So I was dealing with a substantially homogeneous material.

Professor Wheeler: Did you ever find so much difference coming from differences in outside temperatures?

Professor Orton: Yes; I think so. If there should be a difference of forty or fifty degrees (and it is not improbable that we should have had as much as that in four or five months) it would make a great difference in the reading of the pyrometer.

Then, there is the factor of time; the fusing of silicates involves three things—temperature is one, time is another, and size of grain is another—these all come in to influence the result. The cone is intended to measure the result of heat-work performed, which is a pyro-chemical process. The pyrometer on the other hand is intended to measure temperature, which is not a chemical process. It is a most effective and valuable instrument for this purpose. I have often said on this floor, and I say again with entire freedom, that the Le Chatelier pyrometer is a valuable adjunct to any clay working establishment, and I advise anyone who can afford it to own one. I have one myself, and have worn out two of the platinum couples and now need another.

But, I do not use the pyrometer to finish the firing of a kiln of clay wares. Clay wares are like cones; their burning involves other factors than that of temperature. In my judgment, cones will continue to be used in the future as they have been in the past, as the best and cheapest effective method of measuring heat-work in silicate mixtures. The pyrometer will still continue to have value for what it is now used, viz., to trace the changes in temperature taking place in a kiln or similar structure. If you have a furnace, where you must maintain a uniform temperature, nothing can

take the place of the pyrometer. If you wish to determine the rate of increase or decrease of temperature, nothing takes the place of the pyrometer. I find it invaluable in many operations. But it does not and never will measure heat work.

Mr. Geijsbeek: I don't say anything against cones. I think they are most valuable. I have bought cones for the last ten years. I think about the first cones ever put in a kiln, I put in myself. I was working with Dr. Seger. But we have on the blackboard the problem which confronts us. You can't explain to the common clayworker that the official melting point of cone 1 is 1150 degrees; if he burns 5 days it is only 1035 degrees, or if he burns in 24 hours, it is 1110 degrees. But if he uses cone one, expecting to get the official melting point of 1150 degrees, and it goes down at 1035° by the pyrometer in a five-days' burn, he loses faith in both cones and pyrometer. Those official temperature determinations were made in five hour burns, and the practical clayworker never burns a kiln in five hours. I don't want to argue that cones are better than the pyrometer of the pyrometer is better than cones; but I think the official melting points should not be used as a guide and that we should establish a new standard. The standard melting points are all right to use in the laboratory, but not in any clay-working industry. They are not true for ordinary practical conditions.

Professor Binns: Perhaps Mr. Geijsbeek is not aware that the official figures have been revised in 1903.

Mr. Geijsbeek: These were made in 1896.

Professor Binns: They have been revised. Mr. Geijsbeek has beautifully confirmed the assuption that the cones are approximately 20° apart. Then he shows that when a kiln is burned slowly, we get results at a lower heat, and a lower cone than when burned quickly. We could not have had a prettier illustration of this very action. I have long tried to convince persons who have asked questions of me that we no longer think of or care for temperatures. They are of purely academic interest. It makes no difference to a clayworker whether the cone melts at one or five hundred degrees. The point is, the cone shows when he gets a certain heat effect on his clay ware, and how to get it again. I do not think, in the fact of these figures, anyone can launch any criticism against cones. To my mind, they are beautifully corrob-

orative. It seems unfortunate that the so-called official temperatures were ever published.

Mr. Lemon Parker: It seems to me sometimes very important to know the temperature to which you burn your material. Suppose it is a matter of shrinkage, and you want to burn your goods to a point where they will shrink no more in the use to which they are to be put. If that temperature is to be 2500°, you want to burn your material to that temperature in order to prevent further shrinkage; whereas, if you use the test piece, it is only a guide to show you your goods are burned hard enough, but it does not show that the material is burned up to the necessary number of degrees. If we had some reliable standard to go by, we could keep the cones for the desired temperature and each kiln could be burned to that temperature without difficulty. For instance, in the case of fire brick required for 2500°, if they are burned to 2200° there will be further shrinkage, the amount depending on whether they are highly silicious or of an aluminous clay. The aluminous mixture shrinks more than the silicious, and you have to burn the aluminous mix to a much higher temperature, because they are naturally used at a higher temperature than the silicious. I think it is sometimes necessary to know to what point the goods are burned in degrees centigrade.

Professor Orton: I will ask you, Mr. Parker, whether in your judgment the people who write to you and ask for a ware burned to some definite number of degrees, really have a fairly accurate idea as to what they are asking for? Do you find that the man who asks for a ware burned to 2500° has any real knowledge as to what his heat is?

Mr.Parker: No; I do not think so; but we once had a case in point. We put some of our material in the bench of a gas works. They were supposed to use retorts at about 2500°, to which point we burn them. There was a failure and we found the stuff completely fused. We knew from the cone tests made that the material would stand thirty-two or thirty-three hundred degrees. The man said he had not had a heat higher than needed to make gas, but I had the means to prove that he had and that my material would stand for more than the heat necessary for gas making.

Professor Orton: You take the stand that it is necessary to

have some standard to go by, cones or degrees or some other expression of temperature?

Mr. Parker: We must have some means of understanding each other, when talking about heats. I don't think it must necessarily be in degrees, if there are any other units. I know it is very difficult to measure really high temperatures in degrees, and the closer we get to the melting point of platinum, the more difficult it becomes. Our customers naturally try to use pyrometers, but I know there is frequently a difference of 700° in the readings given by different pyrometers under substantialy the same condition. Gas works are supposed to use material at twenty-four or twenty-five hundred degrees, and we make our material so it will stand between thirty-one and thirty-two hundred. They don't use cones and we do.

Mr. Geijsbeek: I was called on by some iron workers to tell them exactly the trouble with their crucibles, which would not stand the desired heat. The manufacturer of the crucibles was using cones, and the other man was using the pyrometer, and the clay was burned under a five days' heat, and did not have the temperature of the official melting point.

Mr. Burt: I would like to ask Professor Orton if he has ever had any calls from the trade for anything between the regular numbers?

Professor Orton: Yes; I have had occasional calls for half numbers and once or twice I have acceded to the request, but I have refused lately to do so. I think sufficiently close results can be attained by watching the behavior of the cone below or above the critical number. One man may hold cone four until it is bent; another until it touches; another until it is flat; another till the edges are rounded, etc. I don't think it is necessary to interpolate any new numbers. I think there are too many numbers now between cones one and eight. Dr. Seger pointed out that the worst weakness in his cone series was that he had put in more numbers between cones four and eight than necessary. I find it almost impossible to make cones four, five, six seven and eight, so that one will not sometimes overtake the other. I make the cones and test them in my kilns until they work all right, falling repeatedly in the proper order, and preserving the proper interval between numbers. I then put them on the market, and the first

man uses them on a long fire, the next on a short fire. It does not follow that the order in which they fall on a short fire will be repeated in a long fire. I wish it did, but it does not. I have bought cones from the German manufacturers, and on testing, have had their number five go down before their number four. Other people in this country who make cones have had the same difficulty. It is a pity Dr. Seger allowed himself to do two things: First, to attach the temperature idea to the cone series; second, to put in so many numbers between numbers 4 and 8. If he had not, they would burn in better relation than they do. But with all their faults, I think the cones have given a pretty fair account of themselves.

Mr. Malcolm Post: In the firing of the kiln, at about the time for the cones to go down, if the kiln atmosphere becomes reducing, does it make the cones come down quicker or slower?

Professor Orton: In the case of the white cone, I do not think it affects either way. In the case of a cone containing oxide of iron, it may make quite a noticeable difference; and, if so, it will melt earlier with reducing atmosphere. It may come down out of its normal place. However, I have found infinitely more trouble from the presence of sulphuric acid in the kiln gases than from reduction. The average kiln, fired below cone one, is oxidizing.

Mr. Volz: Does it not depend a good deal on the way the kiln is fired as to when the cone goes down? I know if we fire our kiln closely and keep the air out, the cone will go down quick. If we fire gradually, and let the cold air strike the cone, it is impossible to get the cone down, after it once chills.

Professor Orton: I had not observed the difference to be so great as that. Most of my firing is done in small kilns where drafts are relatively strong and most of my cones do get chilled by drafts in the process of firing. I am more used to observing their behavior under such conditions than any other.

Professor Wheeler: The great objection to and fear of the Seger cone, which I have always had, if it becomes the standard, and is made by everybody, is the fact that it is a complex mixture, theoretically easy to make, but practically very difficult. That is the weakness of the Seger cone. I allude to that as a practical difficulty, and there is only one practical way to eliminate it, and

that is to do as as the Germans have done, i. e., have them all furnished from one place. In this country, I believe nearly all cones are coming from one place, and as long as Orton is making them, I think we can rely on their being conscientiously made, as far as possible. As soon as Tom, Dick and Harry make them we will get cones telling all kinds of tales. Mr. Geijsbeek's paper brings out the fact that if carefully made, there is reliability about them. The series here is as close as we could get by the Le Chatelier pyrometer, and I believe I am supposed to be prejudiced in favor of the pyrometer.

There are also the difficulties which Professor Orton has referred to, which I have not found under the uniform conditions which I use. You can't say to a workman, "When the needle swings up here it is a certain temperature." Anyone using the Le Chatelier pyrometer is using a refined instrument, and must constantly check it by using pure gold or silver as a standard melting point.

I cannot explain the glass ratios, unless the tests were made in winter and summer. But this sequence here, and that there (indicating table on blackboard), is certainly flattering as showing what can be accomplished with the Seger cone. It also brings out another thing, and that is the fact that it is impossible to make a dogmatic statement as to what the fusion point of a certain cone is, any more than you can say that phosphorus melts at a certain temperature. While yellow phosphorus melts at a certain temperature, red phosphorus does not. Yellow sulphur has one melting point and brown sulphur another. The separation of chemical and physical problems is very difficult. So here again we have to consider physical conditions—there a slow, and there a rapid heat. All we can say is that under these conditions the cone goes down at that point (indicating), and under those conditions it goes down at that. So we must qualify all these statements.

This paper is very valuable and brings out strongly the fact that when we make dogmatic statements, we must state conditions.

I am very much pleased to see that Seger cones can be practically brought to yield a regular sequence, in this instance as satisfactory as the Le Chatelier pyrometer. But I do not agree with Profesor Binns, that we should sleep and wake in cones. Per-

haps that would be possible if we lived on the potter's wheel and in the clay bin, but if we want to make our work scientific in value, so that it may be used intelligently by those in other fields. We must not isolate ourselves in language which others do not understand. When we speak of Seger cones, we must give approximate temperatures—under certain conditions the temperature is so-and-so. You must qualify the conditions. Don't think you can separate Seger cones from the methods by which all records are measured in the scientific world.

Mr. Post: I will give you an illustration to show that Seger cones are sometimes more sinned against than sinning. Three years ago we started to use Professor Orton's cones and got along nicely for awhile and had good results. Finally the kilns began to come light and were not burned to a high enough temperature. A week or so afterwards, I found in some of the kilns cone number seven down and number six standing. It went along for awhile and I finally got suspicious and watched the fireman. I found that the fireman in putting in the hook to pull out a trial piece would give a shove and push the cone over and thus get through with his kiln earlier, tho the kiln was being burned off light.

FAIENCE VS. MAJOLICA.

BY

STANLEY G. BURT, Cincinnati, O.

One of the necessary factors for scientific advance is a perfectly distinct and definite terminology. Without it there can be nothing but confusion in all exchange of ideas. When we read of cast or wrought iron we know what is meant, but when we read of Faience, Majolica, China, or Porcelain, are there any two of us who have exactly the same conception of what is meant?

I think you will all agree with me on the desirability of our terminology meaning something definite, but how is it to be accomplished? Clearly not by anyone person attempting to lay down the law, but rather by a free discussion aiming to arrive at a definition satisfactory to at least the majority.

It is my purpose here to state my views merely on what the two words Faience and Majolica should stand for. Of course, no one could give a definition that would not leave a great deal to be justly said against it, but let us try to reach that definition which is open to the least just criticism.

The Century Dictionary says of Faience that is is a fine kind of pottery or earthenware, glazed and painted with designs. The term is loosely used for any ware between porcelain and common unglazed pottery." The distinct part of this so-called definition is that the word is loosely used and means practically anything. Of Majolica it says: "Decorated enameled pottery, especially of Italy, from the fifteenth to the seventeenth century." Here we have something definite, namely, Majolica is enameled ware. Webster is even more hazy. He says Faience means everything, even porcelain. How hopeless this is. Here we have earthenware pottery, Faience and Majolica, all meaning the same thing. In fact, all writers on pottery that I have ever read fail to make any distinction clearly defined between Faience and Majolica. There seems to be a tendency to drop the word Majolica altogether, ex-

cept where referring to the old Italian ware, and to use Faience for all pottery except china and porcelain. This is especially true with French writers. Brougniart, for instance, classifies pottery into two main groups, one with soft body, that is not vitrified body, the other having hard or vitrified bodies. Under the first head he speaks of "Common Faience," and Faience with a tin enamel, while under the second he speaks of "Fine Faience." Deck, commenting on this, justly claims that the fineness of the product does not necessarily depend upon the character of the body and says he would dislike to call Faience of Rouen and Urbino common. Note that it doesn't worry him in the least to call these both Faience, although both are without any doubt Majolica. He then goes on to say, "In default of a more generic name, I consider all pottery having an earthy fracture Faience," and explains further that it may have a glaze or an enamel. So he calls the clear glazed ware of Palissy and the beautiful Henri II. ware Faience, and the enameled Rouen ware the same.

Our own Professor Binns in his most delightful book, "The Story of the Potter," as far as I can see, makes no distinction between Faience and Majolica. He says, referring to the old Italian ware, "The name Majolica, given by universal consent to these enameled wares," and tells how the Moors abandoned their clear alkaline glazes on reaching Spain and made tin enameled ware instead. Later we find him as all other writers, speaking of the Faience of Rouen, although he tells us that it is technically the same as the Italian Majolica, except that cobalt was mainly used in the decoration.

In fact I must freely confess that in the view I am about to give you I fear I stand alone. However, I feel my argument is good and trust I may be able to convince you.

When we speak of Majolica, what product is first suggested to our minds? Undoubtedly Italian Majolica. That this distinct class of ware is Majolica we all agree. Then let us see what are its peculiar characteristics.

In the first, we note that it is made of a very crude body, which is always so charged with iron that it never burns white, and is often almost red. Taking next the glaze, we find it is not glaze at all, but is an enamel. Here I come to another case of lax definition, the indiscriminate use of the words glaze and enamel.

An enamel is always opaque, and a glaze transparent, so I claim it is wrong to call an enamel a glaze or vice versa. Returning, however, to the subject in hand, we find we have a crude colored clay body, covered by an opaque, generally white, enamel, and that there is no question about this being Majolica.

The first porcelain brought to Europe from China by the Dutch must have seemed to the potters of that time simply marvelous, because it was pure white throughout. Such a thing as kaolin, a clay that would burn white was absolutely unknown to them. Naturally this porcelain brought high prices, and our Dutch home potter was in despair until he discovered how to make an imitation of it. This he accomplished by covering his coarse yellow to red body with an opaque white enamel, upon which he painted copies of the Chinese designs. However, his product was never porcelain, but merely Majolica. That is, he concealed his colored body with enamel, and then painted on this enamel. The fact that he often put a final clear glaze over his painting, did not alter the case. The so-called Rouen, Faience, was of the same character and, therefore, is a Majolica.

My definition of Majolica is, therefore, pottery in which the body, of colored clay, is concealed by an enamel. If any potter should be so foolish as to pay for white clay and then cover it with an enamel, he would still be making Majolica.

With Faience, the case is not nearly so clear. The word is derived from Faenza, a town in Italy, where pottery was made as far back as 1300 A. D. Now, unfortunately, this pottery was technically identical with Italian Majolica and so the word was also used, meaning this ware, and is so used today. If Majolica clearly defines the class of ware of which we have been speaking, why confuse ourselves by also calling it Faience, especially as these names in this case are absolutely identical in meaning. Is it not better to let Faience stand for a distinct group of its own?

With this in view, I define Faience as pottery in which the colored clay body is covered by a transparent glaze. The Faience potter may use a highly colored clay, as in yellow ware, or he may use clays closely approximating white, as in Rookwood, but he always glazes it and never enamels it. Here some might claim that ware, such as Rookwood, could not be called Faience, as it conceals the clay color proper with colored clay slips. But the

distinction I draw is in the use of an enamel or a glaze, and Rookwood uses glaze and is, therefore, a Faience. If you care to make white glazed brick, you can either make Majolica brick or Faience brick. If you cover your clay with white enamel you will make Majolica brick, while if you give a white slip face to your clay and then use clear glaze you will make Faience brick.

In the two definitions I have given you, you will note that both have colored clay bodies. In the case of Majolica, I explained that a white body would never be used, as it would not pay to hide the fact if you were paying for such good clay. In the case of Faience I say colored body, because here, when absolutely pure white is used, I consider that we have passed out of Faience entirely and are now making either china or porcelain.

One of the main objects of this classification is to give a better understanding of the possibilities of decoration in the two classes. Pottery decoration I divide into four clases:

First. Modeling or incising the clay body.

Second. Coloring the clay body before or after firing.

Third. Coloring the glaze or enamel.

Fourth. Coloring on the glaze or enamel.

We see at once with our definition of Faience that all classes of decoration can be used either separately or combined, as desired, while with our definition of Majolica, we see that the great second class cannot be used. This second class, that of applying color to the body, includes, first, the use of the color natural to the clay, as in yellow ware; second, applying colored slips; third, all print or transfer work; in short, what we understand as underglaze decoration, all of which would, of course, be valueless under an enamel. So that Faience stands for underglaze decoration, while for our main decorative effect in Majolica we are driven to the fourth class, that of color on the glaze, or as it is generally known, overglaze decoration.

In these two great pottery groups I know of no better examples that the Italian Majolica and the Rookwood Faience. I think you will agree with me that it would be as well to call a German a Chinaman as to call both of these wares Majolica or both Faience, or to say that ware with an opaque enamel and overglaze decoration was the same as ware with a clear glaze and underglaze

decoration. Let me, therefore, repeat my definitions, which I trust may meet with the approval of the society.

Faience is pottery in which the colored clay body is covered with a clear glaze.

Majolica is pottery in which the colored clay body is concealed with an opaque enamel.

DISCUSSION.

Professor Charles F. Binns: In the modern nomenclature, I agree entirely with Mr. Burt. He is correct in his statement that faience was derived from the town "Faenza" in Italy, where this class of ware was made, and from whence it was introduced and for a time confined to the town "Nevers" in France, where it was made in a little pottery and the ware called "faience." In majolica there is also a contradiction of terms, because the name is not derived strictly from the Italian, but from the Spanish. For these reasons, we must depart from historical associations and establish just what we mean. In this connection, I would like to appeal for a correction in spelling and pronunciation. I think we should spell "majolica" "m-a,i- as we pronounce it. I think we should sepell "faience" "f-a-y-e-n-c-e" and so pronounce it. I think it is more in accord with modern methods. Mr. Burt is perfectly right in his definitions. They raise another point, however. I suppose it was meant to apply the terms to decorative ware, but I presume yellowware bowls would, technically, belong to the same class. I should not apply the definitions to these things, however, but rather to decorative pottery or art ware, rather than to table and utilitarian ware.

Mr. Burt: I think according to my quotation from Mr. Deck, the French, who are the main users of the word faience—"fayence," use it to cover all classes of ware having an earthy fracture. He speaks of them all as faience.

Mr. S. Geijsbeek: The paper of Mr. Burt is a very excellent one and gives opportunity for this Society to express its sentiment and change something which is wrong in the public mind. I think this society should by resolution adopt Mr. Burt's definitions of faience and majolica. I move that.

Mr. Burt: We can at least say "glaze" when we mean it, and say "enamel" when we mean enamel. When we talk about a "white

glazed brick," heavens know whether we mean a white enamel, a white glaze over a white brick, or what not. We can agree that when we mean a glazed brick, or an enamel brick, we will say it. Today we don't know.

Professor Binns: Mr. Geijsbeek suggests that we should put the matter before the public. I do not think we have any status from which to dictate to the public on such a matter as this. In regard to the definitions of glaze and enamel, we look to the French for many definitions, for they are proverbially accurate. They use three terms for glaze, viz., converte, a porcelain glaze; vernis, representing the true earthenware glaze; and emaile or enamel.

I think we should be all right in the definitions proposed, if it were not for the troublesome matt glazes. We can define glaze as transparent and enamel as opaque, but where are you going to put the matt glaze? (For myself, I am quite content with the broad definition—the enamel is opaque and the glaze transparent.) Notwithstanding that, it is possible to have a transparent enamel and an opaque glaze.

Professor Orton: Where the transparent enamel comes in?

Professor Binns: In majolica colors. Suppose we take majolica glaze, rendered green with oxide of copper; we have a transparent green color.

Professor Orton: If it is transparent it is still a glaze, but if the amount of copper passes a certain point, it becomes matt, and we then have an enamel.

Professor Binns: Then we have both majolica and faience in one.

Professor Wheeler: (Addressing Mr. Burt.) Do you class your matt goods as majolica or faience.

Mr. Burt: We class them as faience. We don't make an absolutely opaque matt.

Professor Wheeler: Do you call Mr. Gates' green "Teco" ware also faience?

Mr. Burt: Undoubtedly.

Professor Wheeler: The Society is indebted to Mr. Burt for bringing this matter up. To say the least, it is a matter about which the average laymen and most technologists are very foggy. He has brought out distinctions which will at least be recognized by technologists, and possibly by the laymen. But this classifica-

tion at best is imperfect, and just where to draw the line is difficult to tell.

In regard to Mr. Geijbeek's motion, I hardly think this Society is in position to attempt to dictate to the public at large how these subjects should be classified. The fact that a paper was read and discussed might have some influence, but I do not think that a resolution would add weight.

But while we are on definitions, I want to bring up what is meant by term "ceramics." The question has been brought up recently as to what is the definition of that term. There is certainly quite a wide difference of opinion in the minds of laymen, and possibly this society has already committed itself in making this broad term known outside of the limits usually recognized as covered by the term "ceramics.'

The average layman thinks it simply applies to pottery and is rather inclined to fortify himself by citing the fact that nearly all ceramic societies not only use the hard sound, and pronounce the work "keramic," and further quotes the Greek word "keramos" as its derivation. This is rather a rather broad term meaning pottery, potters' clay or earth. But the word ceramics is not derived from keramos, but from kerameous, an adjective meaning "of clay," or "earthen," and I think from that word the Society has a perfect right to apply the term to all clay-work, whether of the potter's wheel or the brick-yard.

I think the majority of people connected with the clay industry now use the term in that sense. I think the public at large have not yet grasped it, but we can afford to be patient. But there now seems a tendency to make this term ceramics also include the cements and glasses. It is true from a chemical standpoint there is a marked similarity in composition between cements and clay-wares, but I think it would be unfortunate to make our well-defined term cover this other product.

When you take up glass, the relationship with clay products, perhaps, is not quite so distant as with cements, still there is a radical difference in the technology, tho we are dealing with a silicate industry in both cases. It is also true that the higher grades of ceramic goods very commonly rely upon the glasses for getting decorative effects, whether in enamel or glaze. But if the glasses are included in the field of ceramics I do not see how we

are to avoid including the metallurgical products also, for where the glass and cement produce one ton of silicates, I think the metallurgists produce ten tons of silicates, which are very closely related chemically to the glases and cements. The silicates produced by the metallurgist are by-products, and not the principal production, but in many respects these by-products are far more important commercially than some kinds of clay products.

But if we insist that ceramics should cover all the silicate industries, it seems to me we are going to entrench upon the profession of the metallurgist. So, as the lesser of two evils, I feel personally inclined to think we had better adhere to the less broad view of the term ceramics, by applying it exclusively to clay wares.

However, I do not want to narrow the work of the society. When this organization was started, a tremendous effort was made by some of us to start it out as a technological society, to take in not only these industries, but also all of applied chemistry. I think there is a gread need in this country for a society covering the whole field of applied chemistry, and it would be well if we could get together an organization like the American Society for the Advancement of Science, a large association of about twelve chapters. But when we organized the time was ripe for a ceramic society, but not for the larger idea and I think we must hope that our work will broaden until we eventually get there. I hope our society will continue to grow and broaden, but I would like to hear the meaning of the word "ceramics" threshed out by the society. I would like to hear Professor Orton on that.

Professor Orton: I think my views are pretty well known on this topic already. I have been waiting to hear other speakers. Professor Wheeler will recall the discussion which was had at the time of the inception of this society, and while the committee on constitution was laboring to prepare something to present to the body soon to be called together. We discussed quite carefully the name which should be given to the organization. At that time, I entertained much the same views as I do now as to the relation of these three great silicate industries. We debated as to whether we should not call ourselves the American Silicate Society, rather than the American Ceramic Society. But, this name did not meet with the favor of the three men who composed the committee, and

the name was made "ceramic," but no attempt was made at a definition at that time.

At the time of organization, we talked about taking up work in all three of the great silicate industries. I refer you to our transactions, to see how far we have done so. We have had several papers on the cement industries, but only one on the glasses; however, I do not despair of getting the glass chemists interested ultimately. So far they are chiefly interested on the mechanical side. Glasses can vary a good deal in proportions, and still make a pretty good article.

The minute you go into the accurate study of glass to find what can be done, you get into as wide a field as the clay industry. The researches of Dr. Schott is Jena justify that statement. I think our constant effort should be to bring all these lines into our programs. I fully appreciate the embarassment which has arisen in the popular mind in regard to the meaning of the word "ceramics." Some have taken the stand that we cannot sharply limit our field to that occupied by these three great industries; that they all overlap, and have much in common.

We have even had in this society a paper on a metallurgical subject, viz.: "On the formation of slag silicates" and showed how closely work in that field was paralleling our own. There is a difference, however; the metallurgist produces slags or silicates to separate the earthy material from his metal, while in ceramics the silicate is the end in view, and is not a bi-product. The metallurgist, the ceramist and chemical engineer are all equally interested on the subject of fuels, and the laws governing their use. It is now taught chiefly as a metallurgical subject, but I don't know why the metallurgist should have exclusive claim to it.

In the Ohio State University, we have organized the work in Applied Chemistry into three parallel courses, each leading to a degree. First, the course in metallurgy, covering the extraction of metals from their ores. Second, the course in ceramics, covering the technology of the silicate industries, claywares, glass and cement. Third, chemical engineering, covering the manufacture of all other products of a chemical nature not included in the two preceding.

In the department of ceramics, the greatest attention has been devoted so far to claywares, but we now have a course in the tech-

nology of cements, including laboratory work in their manufacture and testing, which so far as I am aware is not yet duplicated elsewhere in the country. We have not yet offered a similar course in the technology of the glass industry, but we have a man, Mr. Purdy, who is preparing himself to take up that line and as soon as he is ready, we expect to give every student in Ceramics the option of these three lines in his senior year.

I realize that the organization of the university's work represents principally my own conceptions of the field, but the work of the American Ceramic Society is the product of many minds and its policy represents the expression of the highest authority on the subject in this country, possibly in any country. Hence, I take great pride in the fact that, so far, the work and literature of the society has been on the broad and catholic basis, and I hope it may continue to broaden, as Prof. Wheeler suggests, rather than to concentrate unduly on any one subdivision of the field.

In confirmation of the attitude taken by Ceramic Society I might add that there is excellent precedent for it abroad. The literature on ceramic subjects in Germany is published chiefly through the Thonindustrie Zeitung Sprechsaal, Deutscher Töpfer und Zeigler Zeitung and a few other sources. These societies collectively represent the clayware, glass, lime and cement industries and they divide it up to suit their convenience. One of them began as a clayworkers journal and is now the world's chief authority on Portland cement; another is a potters' journal, but is very good, also, on glass, etc.

There is no society called the German Ceramic Society, and no one organization occupying our exact field. The one which comes closest to it is, perhaps Der Deutsche Verein für Fabrikation Thonwaaren, Kalk und Cement.

If the society thinks it wise, we might change our name to the "American Society for the Study of Clay Wares, Limes, Cements and Glass."

Professor Wheeler: I did not want to bring up a change of name of the society. I think under our name we can do anything we want to. I think it is well to encourage the cement people to come here; we can help them and they help us. There may come a time when we will have to form branches covering the various subjects, and when that time arrives we can take it up. My object was merely to bring out a discussion as to the meaning of the word "ceramics," the name of our society.

HEAT CONDUCTIVITY OF REFRACTORY CLAYS.

BY

H. A. Wheeler, E. M., St. Louis, Mo.

In the manufacture of refractory ware, the primary requisite is to obtain a body that will retain its shape and carry its burden without deformation from softening or fusing. Where only a "dry" heat has to be withstood, as in kilns for clay wares, lime-kilns, heating and enameling furnaces, regenerators, hot-blast stoves, copper and iron roasters, coke ovens, etc., the physical ability to successfully withstand the heat is the principle requisite of a fire brick. Where a "wet" heat or the corrosive action of slags has also to be withstood, as in blast furnaces for iron, copper and lead, lead roasters, open-hearth furnaces, converters for steel or copper, puddling furnaces, glass tanks, cement kilns, gas-producers, fire-boxes, etc., the chemical composition of the body is very important, and should be given quite as much attention as the physical ability to merely withstand the heat. In all these applications of fire brick the factor of heat conductivity is of subordinate importance, though the less the rate of heat conductivity, the less will be the loss of heat and hence the more economical in fuel, a matter that is rarely, if ever, considered by either the manufacturer or consumer.

There is another class of refractory goods where heat conductivity is of great and fundamental importance, as in retorts for gas making, zinc smelting and assayers; crucibles for assayers, melting steel, brass, and alloys; glass pots, and saggers. In these applications the ability to rapidly transmit heat adds greatly to the value of the clay, and in some cases is the most important commercial factor, though the writer is unaware of its importance being appreciated by the fire brick manufacturer. If two retorts of equal refractory value have a marked difference in their ability to transmit heat, the better conductor will accomplish the result in less time, and be that much more valuable in increasing the output

for the same investment over the poorer conductor of heat. In some instances this saving in time, and, therefore, enlargement of the output, would make the better heat conducting clay worth several times the value of the poorer conductor. Some of the more advanced consumers are beginning to realize that mere life of a retort is of secondary importance compared with securing a larger output from the same plant. For one of the fundamental principles of modern technical economy is in securing the maximum output from a given plant, as this saves in the labor, fuel, interest and fixed charges.

Even in the application of clays to structural purposes and domestic goods, the heat conductivity is a factor that adds or detracts from its desirableness, and in the great majority of such applications the poorer the conductivity the more desirable the clay, other things being equal. But it is in retorts, crucibles, glass pots and saggers that heat conductivity will be of the greatest importance, and there the output or expenses in operating a large plant may be considerably influenced by a proper selection of suitable clays.

The writer is unaware of any studies having been made on the heat conductivity of clays beyond the broad physical statement that they are relatively poor conductors. So when recently consulted by a client for advice as to the relative heating value of different makes of gas retorts, it was evident that experiments would have to be made on original lines in order to give specific working values.

The inquirer had observed marked differences in the speed with which different makes of retorts worked off their charges, and to determine whether it was due to the clay or to the method of making up the retorts or to the design of the furnace the following experiments were made.

Samples were requested from the manufacturers of gas retorts, who were asked to furnish slabs from fresh, clean retorts that represented (a) a normal burn, (b) an over-burn, and (c) an under-burn. Four different factories responded, but with one exception, there was no appreciable difference in the samples furnished from a normal burn, which is intentionally made soft, to enable the retort to withstand the violent changes in temperature to which it is exposed in the act of charging, when fresh coal that is often wet and icy in winter, is suddenly thrown into

the red hot retort. These samples were supposed to be three inches thick, and the difference makes are designated as "W," "X," "Y" and "Z."

The samples were trimmed down to 6½x8½ inches, except "W," of which only one sample was furnished, and it was 4x8. This undersize was very unfortunate, as it prevented direct comparisons being made with the other samples, though its value could be approximated by correction.

Sample "W" is convex, and, therefore, from the sides or top of the retort. The body is rather tender, porous, and soft burned. It contains considerable grog, perhaps thirty per cent. or so, which is coarse, and consists of mostly pre-burned clay with some coarse quartz sand. The inside is glazed with a transparent film of glass (to reduce gas leakage).

Sample "X" comprised four specimens that were all well burned, strong, and contained, perhaps, twenty-five per cent. or so of grog. The grog consisted of pre-burned clay and was rather fine, except in No. 1, in which it was very coarse.

Samples Nos. 1, 2 and 3 were flat or from the bottom of the retort, while No. 4 was convex, or from the sides or top.

Sample "Y" consisted of three specimens that were all flat or from the bottom, and were very similar in texture. The body was very tender, porous, and soft burned. The percentage of grog was very heavy, or, perhaps, fifty per cent. or so, rather coarse, and mainly consisted of pre-burned clay, with some coarse quartz sand. The inside was smeared with a brown slip (to reduce gas leakage.)

Sample "Z" consisted of three specimens, two being flat and one convex. They were similar in texture, rather porous, rather strong, and fairly well burned. The percentage of grog was large or about thirty-five per cent of medium size, and consisted of pre-burned clay.

The samples not only differed in thickness, but were found to vary 2-100 inches to 10-100 inches in thickness, as determined by calipers, in different portions of the same specimen, and the thickness subsequently given was the average at the place tested. As gas retorts are poor conductors of heat, the thickness is a very important factor, as increase in thickness produces an increase in the resistance to heat transmission.

While this is a theoretical premise, it is well borne out in actual results.

The samples that were *convex* give somewhat better results than *flat* samples of the same material. This is due to a slight concentration of the heat produced by the convexity, and a similar benefit would be obtained in actual practice. There were sufficient flat specimens, however, to obtain satisfactory comparisons of the different samples, without having to consider this slight benefit due to convexity.

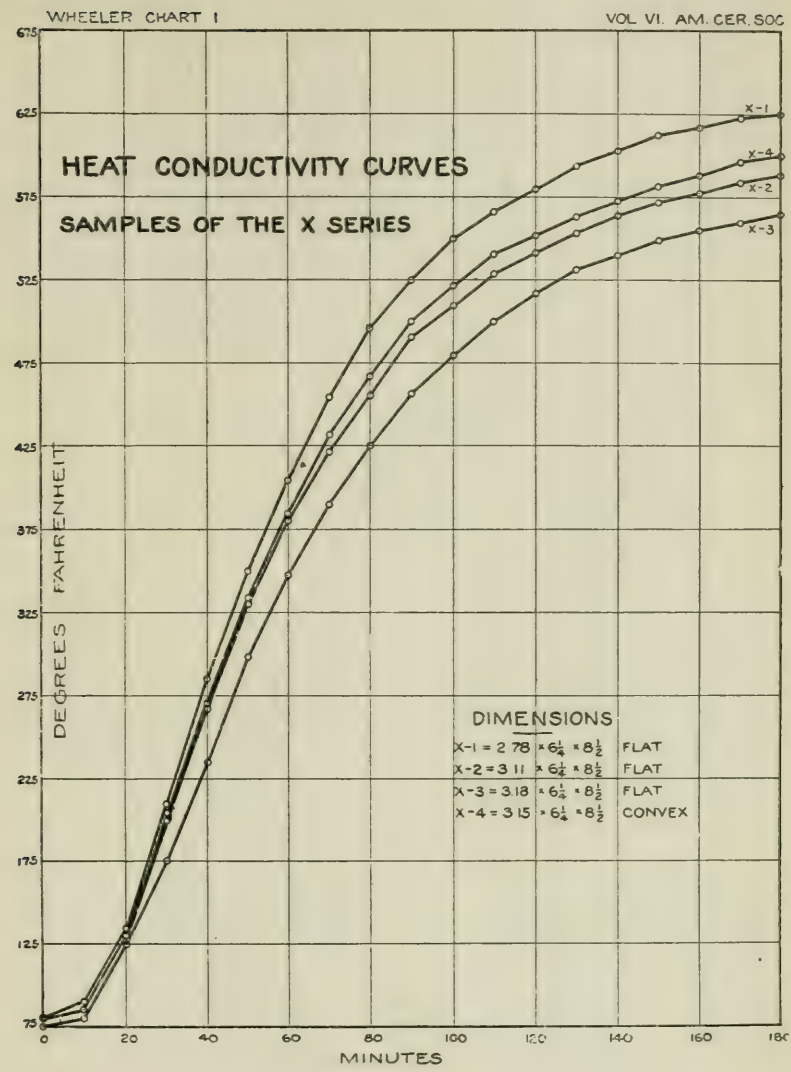
Method of Testing :

After considerable experimenting to determine a method that would correspond as nearly as possible to the working conditions, and which could be controlled so as to give uniform conditions, the following method was employed.

A small rectangular brick furnace was built that was 7¼ inches high, 8½ inches deep, and six inches wide in the clear. The side walls were four inches thick, and ¼-inch thick asbestos boarding was used for the front and back walls. The specimen was set across the top of this furnace, leaving a 1x6 inch slot each side for the escape of the gases. The underside of the specimen was heated to a bright red heat by a special Bunsen gas burner placed in the furnace, and the temperature of the top or opposite side was taken every ten minutes with high grade thermometer (Green), the bulb of which was covered with steel filings ,to ensure a good contact. The entire top of the specimen, including the thermometer, was covered with eight thicknesses of heavy asbestos cloth, which aggregated 1½ inches in thickness, to prevent radiation.

A double shield of white asbestos board was set on the stem of the burner, to reflect the heat back onto the specimen, and the furnace was kept continuously hot. With these conditions duplicates checked satisfactorily.

The temperature was read every ten minutes from the time the specimen was set on top of the furnace until it had nearly attained its maximum temperature. Starting with atmospheric temperature or 74 to 82 degrees F., it was found that the increase in heat shown by the thermometer, or the rate of transmission through the specimen, with the underside at a bright red heat (or about 1400 degrees F.), was *very slow* for the first ten minutes, in fact,


WHEELER CHART 1
VOL VI. AM. CER. SOC
HEAT CONDUCTIVITY CURVES
SAMPLES OF THE X SERIES
X-1
X-4
X-2
X-3
DEGREES FAHRENHEIT
675
625
575
525
475
425
375
325
275
225
175
125
75
0
20
40
60
80
100
120
140
160
180
MINUTES
DIMENSIONS
X-1 = 2 78 × 6¼ × 8½ FLAT
X-2 = 3 11 × 6¼ × 8½ FLAT
X-3 = 3.18 × 6¼ × 8½ FLAT
X-4 = 3 15 × 6¼ × 8½ CONVEX

no increase with the "Z" series. It was less slow for the next ten to fifteen minutes, and after twenty minutes, the increase in heat or the *rate of transmission,* was *very uniform* and *regular* in every case for about an hour thereafter. This rate of increase practically follows a straight line, as shown in the accompanying diagrams. These charts give the information as to the time heated and temperatures obtained, in which the ordinate or *vertical* ranges are the *temperatures,* and the abscissae or horizontal ranges are the times. From thence the *rate* of transmission was less rapid as the top became hotter, until in three hours the top has become nearly as hot as it could be made by this outfit, and the curve became nearly flat. The curves became flat or horizontal when the heat was continued for about an hour longer or about four hours in all, though this is not shown in the the charts.

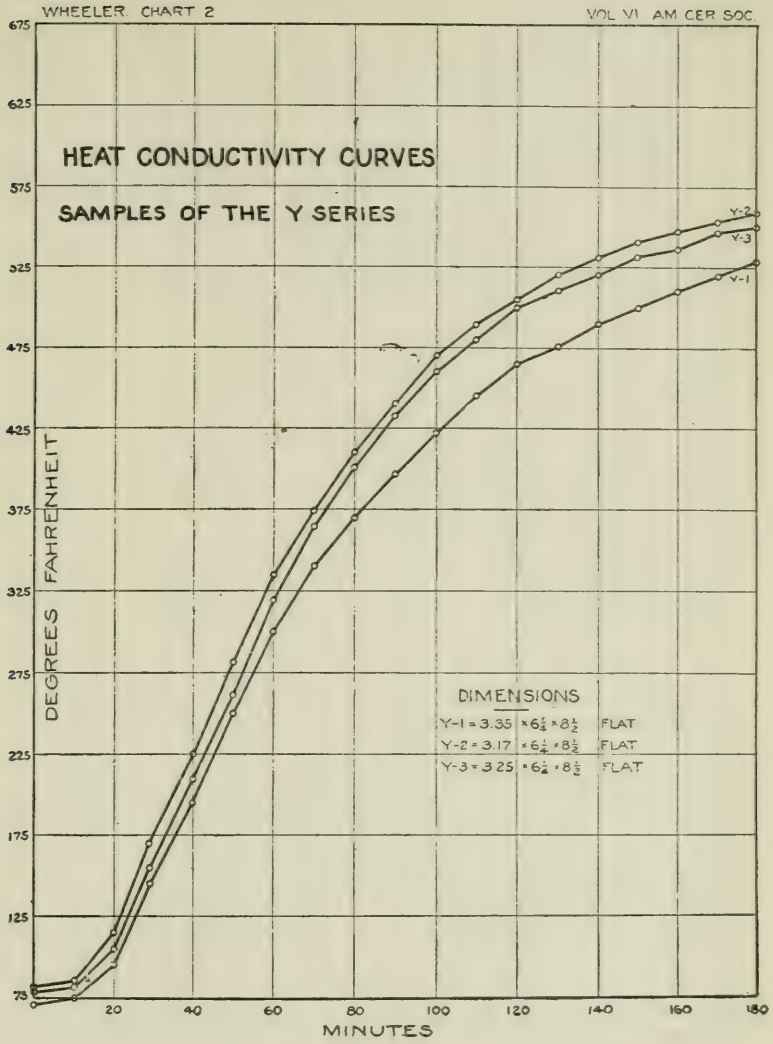
The curves show (for the *same size* samples) a most striking similarity and a very marked regularity, considering that there is more or less *variation in the thickness* of each sample, in the *texture* from air-cavaties and lack of uniformity in mixing the grog, and some *inequality* in *size,* as the blocks were hand-trimmed with a chisel. They show, after ten to twenty minutes heating, a very regular absorption of the heat with only a moderate amount of radiation for one to one and a half hours, or to a temperature of four hundred to four hundred fifty degrees F., after this the radiation increases, with a consequent decrease equal to the absorption of heat, when the temperature becomes stationary and the curve becomes flat, as the sample has attained its maximum temperature.

Discussion of the Results.

A study of the curves shows a marked difference in the heat conductivity rate of each group or make of samples, as well as between different specimens from the same manufacturer.

The sample "W," of which only one specimen was furnished, must be eliminated in the comparisons with the other samples, as it had about forty per cent. less volume, and, hence, would heat up very much quicker for the same quantity of heat.

By experimenting on a similar narrow specimen of one of the other samples, it was found to increase its heat conductivity rate in about the same ratio as its volume was diminished. By correcting from this basis, and again correcting for its convexity and thick-


WHEELER CHART 2
VOL VI AM CER SOC
HEAT CONDUCTIVITY CURVES
SAMPLES OF THE Y SERIES
Y-2
Y-3
Y-1
DEGREES FAHRENHEIT
675
625
575
525
475
425
375
325
275
225
175
125
75
DIMENSIONS
Y-1 = 3.35 × 6¼ × 8½ FLAT
Y-2 = 3.17 × 6¼ × 8½ FLAT
Y-3 = 3.25 × 6¼ × 8½ FLAT
20
40
60
80
100
120
140
160
180
MINUTES

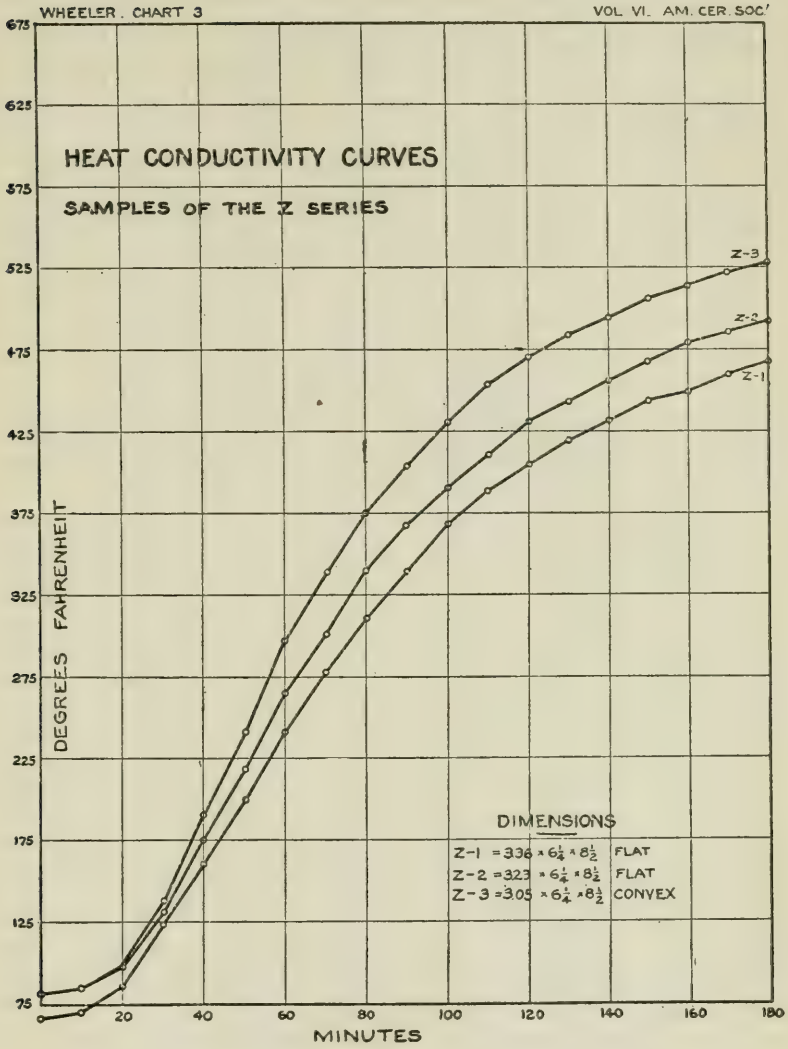
ness, it seems probably that the "W" sample would be equivalent, if flat and of the same thickness, to specimen "Y" 3, and this "W" sample will not be further discussed.

Before considering the individual rate of heat conductivity of each clay, there are other physical factors entering the different specimens from the same clay or factory. These physical factors are: Thickness, Specific Gravity, Porosity, Grog, and Shape, and their value in the specimens tested is shown in the following table:

Table of Physical Factors.

Specimen.	Thickness in inches.	Specific Gravity.	Per cent. Absorption in 24 hours.	Hardness	Grog.	Shape.
1-X	2.78	2.43	8.3	6	low	flat
2-X	3.11	2.42	8.5	5	low	flat
3-X	3.19	2.41	8.0	5	low	flat
4-X	3.15	2.37	7.3	5	low	flat
1-Y	3.35	2.27	13.7	3	very high	flat
2-Y	3.17	2.30	13.8	3	very high	flat
3-Y	3.25	2.30	13.6	3	very high	flat
2-Z	3.32	2.36	11.2	4	very low	flat
3-Z	3.04	2.35	10.7	3½	very high	convex
1-Z	3.36	2.41	10.6	4½	very high	convex
W	2.78	2.26	11.9	4	high	convex

Thickness—The factor of thickness is very important, as is well shown in Nos. 1, 2 and 3 of the "X" series, in which the other physical factors are so nearly alike as to make these an excellent comparison of its value. For the same reason, Nos. 1, 2 and 3 of the "Y" series clearly show its bearing and value. The results of all the tests made show that the heat conductivity rate varies inversely as the thickness, or the thinner the retort, the more rapidly it will work off its charge. Of course, there is a limit in practically applying this, as the breakage will become too great if made too thin, and it will require intelligently directed experience to determine how thin a retort can be made to withstand ordinary usage, in order to increase its efficiency. A decrease of ten or fifteen in thickness, at least in such strong clays as "X" and possi bly "Z," could probably be safely made, and thus improve their value ten to fifteen per cent.


WHEELER. CHART 3
VOL. VI. AM. CER. SOC.
HEAT CONDUCTIVITY CURVES
SAMPLES OF THE Z SERIES
Z-3
Z-2
Z-1
DEGREES FAHRENHEIT
MINUTES
DIMENSIONS
Z-1 = 3.36 × 6¼ × 8½ FLAT
Z-2 = 3.23 × 6¼ × 8½ FLAT
Z-3 = 3.05 × 6¼ × 8½ CONVEX

Specific Gravity.—As a broad rule in physics, an increase in specific gravity increases the thermal rate of conductivity. A study of the data, in which there is only a moderate variation in the specific gravity, does not show any marked bearing, and as this factor also reappears in the individuality of the clay itself, it will not be farther discussed.

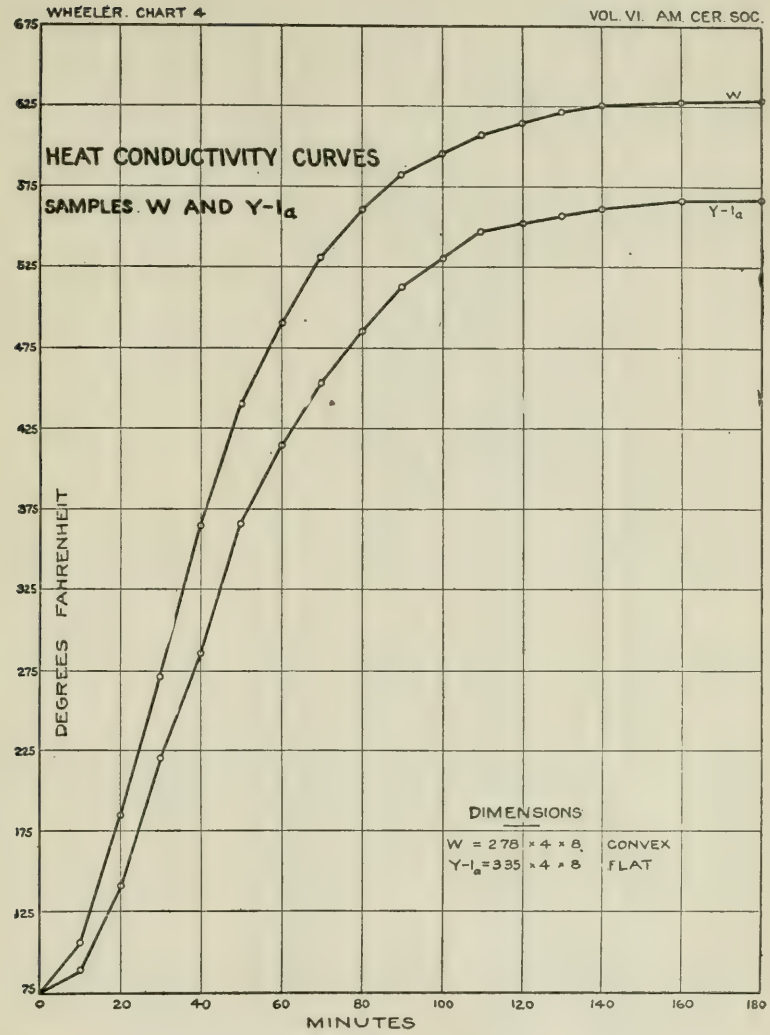
Porosity.—Another general rule in physics is that increase in porosity is best obtained by the increase in weight resulting from soaking in water. After testing the absorption by soaking in water from one hour to five days, it was found that if the dried sample was soaked twenty-four hours it gave satisfactory data as regards its porosity.

As the porosity decreases the harder retorts are burned (and would be entirely eliminated if vitrified like glass) and as the hardness increased the harder a clay is burned, the hardness (as measured by Moh's scale of hardness in which soft clay is one and the diamond is ten), was also determined to estimate the burning and consequently, to a considerable extent, the porosity.

While a study of the data shows that the "X" series, which have decidedly the least porosity as measured by the low absorption and high hardness, are decidedly more efficient, still this factor as a whole, shows only a small influence, and the data at hand is too meagre to estimate its value. Like the specific gravity, this factor will more strongly show in the clay itself and its treatment, so it will not be further discussed.

Influence of Grog.—The "grog" or non-shrinking material that is used in the body to reduce shrinkage and prevent cracking in drying and burning, and to also enable the retort to withstand the violent changes in temperature in charging, was found to vary greatly in kind and amount in the samples submitted. While the data indicates that an increase in grog decreases the heat conductivity, this is a matter that cannot be discussed from lack of information that the manufacturers decline to furnish. It is best considered in the individuality of the report, as each maker has his own ideas as to the quality and quantity of grog required to produce the best retort.

Shape.—A convex shape increases the thermal gradient, as shown by the tests and as indicated by theory. But as enough flat


WHEELER. CHART 4
VOL. VI. AM. CER. SOC.
HEAT CONDUCTIVITY CURVES
SAMPLES. W AND Y-I_a
W
Y-I_a
DEGREES FAHRENHEIT
MINUTES
675
625
575
525
475
425
375
325
275
225
175
125
75
0
20
40
60
80
100
120
140
160
180
DIMENSIONS
W = 2.78 × 4 × 8 CONVEX
Y-I_a = 3.35 × 4 × 8 FLAT

or similar types were sent to make satisfactory comparisons, this will not be further considered.

Heat Conductivity of Different Samples.—While the previous factors undoubtedly have some influence on the heat conductivity of fireclays, it is less than anticipated, and will require considerable additional work to determine. The main influence seems to be the individuality of the clay that makes up the body of the samples, and this is shown in the following table. This table is prepared by taking off from the chart the different times it takes for each sample to attain a temperature of 400° F. For up to this point the rate of increase is very regular in all the samples and practically follows a straight line.

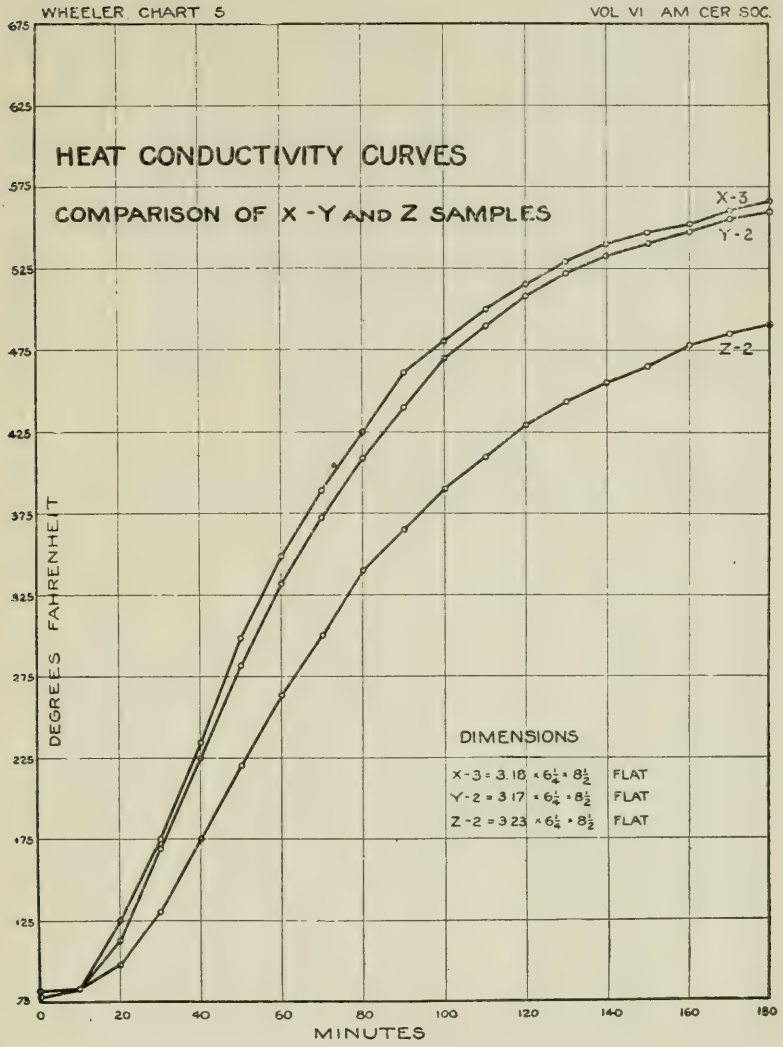
Relative Conductivity of Heat in Attaining 400° F.

Sample.	Shape.	Thickness in Inches.	Time to reach 400° F.	Rel. time Conductivity.	Remarks.
1-X	flat	2.78	59 min.	100	
2-X	flat	3.11	64½ min.	109	
3-X	flat	3.19	72½ min.	123	
4-X	convex	3.15	62½ min.	106	
1-Y	flat	3.35	88 min.	149	Corrected to same starting temperature.
2-Y	flat	3.17	77½ min.	131	
3-Y	flat	3.25	80 min.	136	
1-Z	flat	3.36	110 min.	190	"
2-Z	flat	3.23	107 min.	178	"
3-Z	convex	3.04	89 min.	150	"

The additional comparison between W and a piece of 1-Y, cut down to approximately the same size, was made, in order to reach thus, indirectly, some idea of W's value.

Sample.	Shape.	Thickness.	Time to reach 400° F.	Relative time Conductivity.	Remarks.
W	convex	2.78	45 min.	76	Volume 40 per cent. less than previous samples.
1-Ya	flat	3.35	57 min.	96	

In the above two tables the relative time conductivity column is obtained by calling 1-X 100, and thus showing the increased time required for other samples to reach the same (400° F.) tem-


WHEELER CHART 5
VOL VI AM CER SOC.
HEAT CONDUCTIVITY CURVES
COMPARISON OF X-Y AND Z SAMPLES
X-3
Y-2
Z-2
DEGREES FAHRENHEIT
675
625
575
525
475
425
375
325
275
225
175
125
75
0
20
40
60
80
100
120
140
160
180
MINUTES
DIMENSIONS
X-3 = 3.18 × 6¼ × 8½ FLAT
Y-2 = 3.17 × 6¼ × 8½ FLAT
Z-2 = 3.23 × 6¼ × 8½ FLAT

perature; thus X-2 requires 9% more time, X-3 23% more, etc., while the smaller samples, W and 1-Y and "A," heat up in 24% and 4% less time than 1-X.

From this table, it will be seen that the three flat X samples require 100, 109 and 123 units of time to attain the same (400° F.) temperature, and that the respective thickness of these samples are 2.78 inches, 3.11 inches and 3.19 inches.

The three flat Y samples require 131, 136 and 149 units of time, and have a respective thickness of 3.17, 3.25 and 3.35 inches.

The two flat Z samples require 178 and 190 units of time, and are respectively 3.23 and 3.36 inches thick.

From these we see that increase in thickness requires more time to attain a given temperature in every case, and that probably the decreased rate of heat conductivity is inversely proportional to thickness, though more data is desirable.

Relative Heat Conducting Value.

Selecting samples from each of the three series, as nearly uniform in thickness as possible, we have the following comparison:

Number.	Thickness in inches	Time Conductivity.	Conductivity Corrected for thickness.
3-X	3.19	123	100
2-Y	3.17	131	108
2-Z	3.23	178	140

Hence retorts or crucibles made from the Y clay will require 8% more time than if made of the X clay, and 40% more time if made from the Z clay. This latter saving would be so large in retort, crucible, glass-pot or sagger practice as to justify sending long distances for the X clay, to secure the economy in fuel, labor and interest and greatly increased output for the same investment that it would give over the Z clay.

Resume.

While these data are derived from gas retort material, they clearly bring out the marked variation that occurs in the heat conductivity of fire clays. It warrants careful investigation of this factor in several departments of ceramics, as the intelligent use of this factor can at least secure decided economy in the operation and plant investment of gas works zinc smelters, steel and brass foundry-work, glass works, potteries, and assay laboratories, if not in several other fields.

Discussion.

Mr. Lemon Parker: In working at a temperature of twenty five hundred degrees, is it your opinion that the same rules would apply for rate of heat conduction as at 400 degrees?

Professor Wheeler: While it is probable that the rate would hold, at least approximately, it is not safe to state this without making the actual experiment.

Mr. Parker: Assuming four charges are made every day, and one retort in the bench is three inches thick, the other three and a quarter; would the difference be very great between the 3 inch and the 3¼ inch on four charges in a day? Would the difference in fuel consumed be material?

Professor Wheeler: It would be very decided; how much, would depend on the particular retorts.

Mr. Parker: A number of years ago we were very busy, and allowed our mould to become worn so that it produced a retort shell three and a quarter inches thick. We furnished some of these thick retorts from it to a customer. Ever since that day, he has thrown it up to me that we never made as good retorts since; simply because the retort walls were thicker and lasted a little better than the average. He never complained of any difference in the fuel bill, but did say that those retorts were much better than any we made before or since.

Mr. Bowman: You have taken into account the amount of grog, but would the size of grog make a difference?

Professor Wheeler: The size of grog is shown by the porosity. That is why I have given the absorption column. With one exception the grog was coarse.

I am glad that Mr. Parker told the experience which he did. That has been the trouble—the users of gas retorts, and zinc retorts, usually look solely at the life of the retort, and they want them made to give the longest life, without considering the real value or heat transference efficiency of the retort. This particular party whom Mr. Parker quotes thought that particular retort was the best, because it had the longest life. If he had been wide awake and kept his books properly, he would probably have found it was the most costly retort he ever had, even though it lasted fifty percent longer. What I have tried to bring out is,

that so far as efficiency for accomplishing the work required is concerned, the thinner the retort the better for rapidly securing the transference of heat, which is the object desired. Practically, they cannot be made as thin as heat transference requires, as they would break too readily from mechanical abuse. The question is, what thickness to make the retort to get rapid heat transference or high conductivity, with a reasonable strength to withstand normal usage. If too thick, we lose in capacity and waste fuel, while if too thin, the breakage becomes excessive.

Mr. Bowman: I will ask Professor Wheeler if he considers that after a retort is once heated, the conductivity is of the same importance in maintaining that heat? In other words, does it require more fuel to maintain heat in a retort with thicker walls, or is it only on the first start in heating up the retort that more fuel is required?

Professor Wheeler: The retort is charged with coal, and you must pour heat into the charge to raise the temperature to the point where the coal distills, and then you must keep pouring it in to keep the charge up to that temperature, as the process of distillation continuously absorbs heat.

Mr. Bowman: In case of a saggar there is no distillation inside.

Professor Wheeler: The thicker the saggar, the more time it takes to reach the proper temperature inside, and therefore the thicker the saggar, the more fuel it will take, as the consumption of fuel increases as the time increases.

Professor Chas. F. Binns: If the heat has to pass through the saggar walls, the thicker those walls the less will go through and the more will pass up the stack without going through the saggar walls. But there is more in this than reaches the eye. Professor Wheeler makes a bold and broad assertion. It is perfectly true that the fracture of saggars is more evident to the eye of the manufacturer than the consumption of coal, but I don't regard it as proven by these statements that the saving of fuel advocated would be necessarily less expensive. I do not think the statement is correct, that the porosity of a piece shows the size of grog, or vice versa. The nature of the grog has much to do with it. If you use a vitreous grog you do not get as high porosity, whatever the size. The burning of the grog has much

influence on the porosity of the resulting piece. It seems there is a point there with reference to the conductivity of very porous clay. It seems as though the conductivity is governed entirely by the presence of air in the cells. In a porous piece of clay ware, it is charged with air and affects the conductivity of the substance. If that is so, the problem is to produce a saggar of greater density that will stand sudden changes of temperature. But if you make a vitrified saggar, your rubbish pile will grow.

Mr. Gates: Unquestionably, as soon as you make a body porous, i. e., full of air cells, non-conductivity ensues. A very porous tile seems to be almost a non-conductor. I have considered the possibility of getting a body which was not at all porous, and which would still stand heating and cooling. I have experimented with clays which were not porous to secure such a material, which would still not perish quickly in rapid changes of heat and cold. The ordinary porcelain evaporating dish illustrates what we want, but is not feasible in large ware.

Professor Binns: I think it is largely a condition of producing an amorphous silicate. They are making porcelain muffles in Germany which can be put in a furnace as long as you like and will not crack. They are used by decorators of porcelain. They seem to be ever-lasting. It is purely a question of the chemical condition of the clay, and the chemical composition of the ware.

Professor Wheeler: Mr. Gates brought up the question of the evaporating dish. The Meissen porcelain crucibles that chemists use are only 1-20 to 1-5 inch in thickness, yet they are rapidly subjected by means of a blast lamp to temperatures as high as 2800°F. They are made of true porcelain, and hence have a vitrified body. The speed of transmission of heat is remarkable, as in five minutes the bottom of the crucible can be raised from a temperature of 70° to 2800°F, and yet without cracking.

Mr. Hull: According to Professor Wheeler, these retorts are not cooled down after one charge is taken out, but the temperature is maintained as nearly as possible. Therefore no time is lost in re-heating. In his experiments it is a case of starting with a cold slab and heating it. In actual practice we start with a hot slab, and it is simply a question of delivering so many

calories. With a difference in temperature between the outside and the inside, the speed of transmission would be so much for a given thickness, and for an increase in thickness it would be necessary in order to get the same rate of transmission to maintain a higher temperature on the outside. The number of calories consumed by the coal in destructive distillation is the same, so there is no loss of heat units in transmitting this heat through the thicker wall. The practical loss would come in from the necessity of maintaining a higher temperature on the outside, and thereby losing more by external radiation, and the sensible heat of the gases going up the stack. But theoretically there is no loss of heat, consequently no loss of fuel, in the internal working of the furnace including the retort.

Prof. Edward Orton, Jr.: The classification of the demands made on the different kinds of refractories has been put with great clearness by Professor Wheeler, and I regard it as a contribution of no small importance. I think, however, he does not establish an exact parallel between the saggar used in the pottery kiln, and the retort used for distillation in pyro-chemical work, where a large amount of work is to be done inside. In the case of the average saggar, the pyro-chemical work carried on in it is comparatively small. The case of a saggar in which a certain amount of heat is necessary to reach a certain temperature and then it is cooled down, is different from the case of a retort where, after the working temperature is reached, a constant stream of heat must be maintained for hours, until cooled down by drawing and charging again.

Professor Wheeler: I cannot understand what difference it makes to the man who pays the coal bill whether the heat is poured in to bring up the heat to a certain temperature or whether it is poured in to keep it up, if the time required is excessive from the walls being too thick or the clay having too low a rate of heat conductivity. In either case he has got to pour heat through the walls of the retort or saggar, and if the walls are thinner he will pour the heat through more rapidly, and hence take less time and therefore less fuel. The co-efficient of heat-conductivity must be taken into account as in the case of the friction of pouring water through a pipe. A smooth pipe, lined with glass, will conduct more water than a rough, wooden

pipe of the same diameter. A kiln filled with saggars made from clay X can be burned off in 10 to 30 percent less time, and therefore with a coal and kiln labor saving of 10 to 30 percent, if the clay X has a heat conductivity of 10 to 30 percent greater than clays Y or Z.

Professor Binns is perfectly right in saying this is a preliminary investigation that should be followed up by much more work, as it is a pioneer contribution in this field. Unquestionably if followed up we will find a great range in relative heat conductivity not only in different clays but in different clay mixtures.

Professor Binns: Professor Wheeler is right as to the conductivity of saggar walls, but it will take much to convince the manufacturer who is paving the roads of his neighborhood with fractured saggars of the merit of thin walls in the saving of coal.

Mr. Hull: Professor Wheeler's illustration of the water pipe is a good analogy. Suppose one pipe has more friction than another, the size of the pipe is the same, and it is thought convenient to maintain a greater head of water in the pipe of greater friction. The quantity of water delivered would be the same in one case as in the other and no water wasted. The head of water in the water pipe corresponds with the temperature on the outside of the muffle, and if the temperature can be conveniently maintained higher in proportion to the increased thickness of the wall, the difficulty is met and the objection overcome. The heat required and heat consumed in either case is the same.

Professor Wheeler: That is a correct criticism. (Illustrates on blackboard). If we have a temperature of two thousand degrees on the outside and one thousand on the inside of a retort, no matter how poor the conductor is, the two thousand degrees will travel and finally get through into the retort. Whether it does so quickly or slowly, there is no loss of heat *per se*. But the percentage of the heat generated which goes through and performs this work is small, as by far larger part of the heat value of the coal goes up the stack instead of through the retort. That is where the loss is in both heat and time. If you will recall the fact that the steam engine only uses two to seven percent of the fuel value of the coal, and the boiler where the heat is carried entirely under, through, and often over the boiler,

only takes up forty to seventy percent of the heat units in the coal, you can perhaps form a relative idea of what a small proportion of the heat of the coal goes into useful work, and what a relatively large proportion goes up the stack, whether you are distilling coal in a retort or heating clay goods in the saggar. Therefore, the quicker a retort or saggar can be heated up and the more rapidly the work can be performed, the less the time in which the heavy stack loss can occur, therefore the greater the economy.

Mr. Hull: Would the charge be worked off quicker in the one case which I cited than in the other?

Professor Wheeler: Certainly.

Mr. Hull: Is your muffle cooled in the meantime?

Professor Wheeler: It is immaterial; if you get the heat into the retort or saggar more rapidly, you can finish your charge sooner, and consequently not only decrease the fuel loss, but also increase the output of the plant.

Mr. Hull: If the heat is maintained on the inside constantly, where is the loss of temperature and where does the difference in quickness come in?

Professor Wheeler: In this particular instance (referring to table on board) in the case of sample "1-X," we have the relative time conductivity given as 100; (reading) "2-X, 109; 3-X, 123; 4-X, 106," etc. There is the difference.

Mr. Hull: Is that a parallel case? Weren't you starting with cold pieces of material and getting your heat through? I maintain your time was taken up in getting the first heat unit through. In the other case your coal would be distilled in the same time no matter what the thickness of the wall of retort, providing your internal temperature was maintained.

Mr. Watts: Don't those figures (referring to figures under heading "Time to reach 400°F) 59 minutes, 64½, etc., represent the relative difficulty of the heat passing through? If that is the original resistance, that resistance certainly must be maintained all along. We know some materials conduct heat more rapidly than others, and I know a change of clay in our saggars made much difference. If that is the relative conductivity, then if you have one thousand degrees on the inside and two thousand on the outside, the resistance which that retort will exert will be indi-

cated not only by the fuel used but by the speed in which the material inside is acted upon. It seems to me there is really no argument there, but that the relative conductivity shown by these figures would be maintained straight through. I don't see why the heat conductivity of a saggar, determined at a low temperature, should not remain substantially the same if determined at a higher temperature. The heat certainly has to pass through, and after it reaches the maximum temperature and the heat remains steady, the relative resistance to its passage is going to continue just the same. I cannot see how it could be any other way.

Professor Wheeler: The last speaker has the correct idea. Here are the facts as to thickness in the second column, and here the results as to time taken to reach 400° F in the next column. How will you explain it? To obtain this temperature it took these different times. To get there we had to heat these pieces 59, 64½, etc. minutes. Therefore the relative heat conducting power of these particular clays vary in this ratio. What causes this difference in heat conductivity is a factor, or the personal equation, of each individual clay, and is one of its special properties. It again brings out the fact so well known to every student in ceramics, that clays are like men in that no two are alike.

Mr. Jeppson: In burning abrasive wheels, we must in order to get the grades of hardness that the wheels are made for, burn to very close limits. In one particular instance where we had trouble with overburning, a saggar with a thick wall was used.

If the gentlemen interested will make three saggars, one with a 1 inch, one with a 2 inch, one with a 3 inch wall, and put a Seger cone in each one, subjecting them to the same heat for the same time, they will find three different temperatures registered by the cones, that is, the cone in the saggar with the thickest wall will show the lowest temperature.

I don't know whether this experience has any bearing on the theory which Prof. Wheeler has just advanced, but it would seem to prove that if the same temperature was desired in a thicker saggar, that we would necessarily require a higher heat in the kiln chamber with the accompanying use of more fuel.

Mr. A. C. Higgins: I am interested in what Prof. Wheeler said about the difference between the convex and flat slabs, because of various experiences we have had in making retort tubes built up of bricks. These tubes were a part of a calciner which is used to drive off the water of combination from bauxite, this being one step in the process of making the abrasive Alundum. The calciner is run continuously for a period of thirty to ninety days, fired with coal and kept as hot as possible. The retort tubes which are built up of fire brick in a fire chamber are kept red hot, and the bauxite is poured in at one end and discharged at the other when the calcining is completed.

We made a considerable number of experiments to get the best shape for a brick, and we finally settled on a brick which is crescent in shape. The inside curvature is that of the inside of the retort tube, and the outside curvature is eccentric to the inside curvature, but of shorter radius.

By this shape we greatly increased the outside surface, exposed to the heat over the plain curved brick, and also got a sort of lens effect, as the heat seemed to be concentrated from the outside surface toward the center of the tube. We believe we obtain greater economy in the use of the fuel by this means. At any rate we are calcining today with less fuel than before we used bricks of this construction. Moreover, repairs are much less than before, and the strength of the tube has been increased. The average thickness is very much less than we could maintain with the plain tube, for the wall of the retort is quite thin where the ends of the crescents adjoin. Also the top and bottom surfaces of the bricks are exposed to the heat at thickest parts of the brick.

The bricks are interlocked by means of corresponding lugs and depressions in their adjacent surfaces.

THE REFRACTORINESS OF NEW JERSEY FIRE BRICK.

BY

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Although much work has been done abroad in determining the refractoriness of fire brick, but few results have been published in this country. During a recent study of the New Jersey clays the writer had occasion to make a number of determinations of the refractoriness of New Jersey products, the results of which may be of interest to the society, and are presented here in somewhat abstract form, the full details appearing in a forthcoming report of the New Jersey Geological Survey.

Historic statement.—The manufacture of fire brick represents one of the oldest branches of the clay-working industry in New Jersey, and is of more importance than is commonly imagined. The New Jersey clays were first used for fire-brick after the war of 1812, and one of the earliest records, according to Dr. G. H. Cook shows that clay was taken from Woodbridge to Boston in 1816, and used for manufacturing fire brick. The value of the clays of the Woodbridge district does not seem to have been widely recognized for some years, however, although in 1855 the statistics, given in the Report on Clays in 1878, show that clay for making 50,000,000 fire-bricks was then being taken annually from the pits at Woodbridge, Perth Amboy and South Amboy.

Perhaps the oldest works in the State was that known as the Salamander works (no longer in existence), where brick were made as early as 1825. A little later, in 1836, John R. Watson, established a factory at Perth Amboy, and in 1868, Sayre & Fisher commenced making fire-brick at Sayreville. The works of W. H. Berry at Woodbridge began operations in 1845, and have continued up to the present day, although in 1896 the name was changed to J. E. Berry.

Henry Maurer & Son established a fire-brick factory in 1865, and M. D. Valentine & Bro. in 1865. The latter were started for

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making "bath-brick," later sewer-pipe, and finally fire-brick and other refractory forms. A branch works located at Valentine on the Lehigh Valley Railroad was started in 1887. Other factories are in operation at Ostrander and Weber. Within the last three years several other firms have begun the manufacture of fire-brick, including the factories erected by the Mutton Hollow Fire Brick Company, and Anness & Potter at Woodbridge, and The Superior Fire Lining Co., at Trenton.

In addition to those already mentioned several other firms have made fire brick from time to time, but the product does not represent a regular item of production.

Raw materials.—The ray materials used are chiefly clays obtained from the several members of the Raritan formation, to which there is added a certain percentage of grog, consisting of ground fire-brick or quartz, and occasionally some of the material known as "feldspar." The latter is not true feldspar, but a gravelly clay, containing pebbles of quartz, embedded in a mass of white clay, the latter derived chiefly from the decomposition of feldspar pebbles, which have decayed after being deposited with the quartz.

The fire-clays vary in their plasticity, tensile strength, fusibility and composition, but the following few analyses will serve to show their range of composition and fusibility.

Sample Number	Constituents.								Clay base.	Free Silica.	Total Fluxes.	Cone of Fusion.
	Silica.	Alumina.	Ferric Oxide.	Lime.	Magnesia.	Alkalies.	Titanic Oxide.	Water.				
1	50.60	34.35	.78	tr	tr	tr	1.62	12.90	87.20	10.65	.78	34+
2	51.56	33.13	.78	...	.12	...	1.91	12.50	83.94	13.25	.90	34+
3	68.67	21.46	.78	...	1.35	...	1.34	6.40	52.82	43.71	2.13	27
4	67.26	23.36	1.63	.25	....	.65	....	6.94	57.47	40.09	2.53	27
5	45.76	39.05	tr	.95	.04	...	...	14.46	98.93	.24	.99	34+
6	69.78	19.86	.62	...	1.24	...	1.96	6.54	49.50	46.68	1.46	30
7	40.64	41.19	3.27	.65	....	...	....	14.74	96.57	.....	3.92	29

1. No. 1 fire-clay, M. D. Valentine & Bro., Woodbridge.
2. No. 1 fire-clay, Anness & Potter, Woodbridge.
3. Top sandy clay, Anness & Potter, Woodbridge.

4. Fire-mortar clay, Maurer & Son, Woodbridge.

5. Ware-clay, W. H. Cutter, Woodbridge. (Not used in fire-brick.)

6. No. 1 sandy clay, McHase Bros., Florida Grove.

7. No. 1 blue fire-clay, J. R. Crossman, Burts Creek.

In this table the second to ninth columns inclusive represent the determinations made in the ultimate analysis. A partial analysis only, of some of the samples, was available, and in these cases the difference between the sum of the substances determined and one hundred was taken as representing the sum of lime, magnesia and alkalies. The clay base given in the tenth column was obtained by considering the alumina to be contained in kaolinite, and figuring the amount of silica necessary to unite with it, and adding the combined water to it; the total of the three then represents the clay base. The difference between the silica necessary to combine with alumina and form the clay base and the total silica, was considered as representing the free silica. The eleventh column represents the sum of the iron oxide lime, magnesia and alkalies. The last column gives the cone of fusion.

In the case of the clays low in fluxing impurities, the fusing point agrees fairly well with the fusing point obtained by Seger for mixtures of kaolinite and silica. Several of these clays, notably 1, 2 and 5 show a high refractoriness, but in the others the fusing point is lowered several cones, chiefly by the iron oxide and titanium present, as well as by a high silica percentage.

Unfortunately, the clays of highest refractoriness exist in but limited quantities and also are deficient in some of their physical qualities, which interferes with a large percentage of them being used in the fire brick.

Method of Manufacture.—The raw material are commonly tempered in ring-pits, but sometimes in pugmills, and then molded either by hand or machine, the latter being usually of the soft-mud type. In every case the brick is repressed and after repressing, they are commonly hacked up to dry and are then placed in the kilns. Hand or machine molded bricks are usually spread on brick drying-floors, warmed by flues passing underneath, and after remaining there a short time, are repressed.

Most of the fire brick manufacturers burn their product in circular down-draft kilns, although one factory has a continuous

kiln, and a few works have rectangular kilns. A few of the fire-brick makers in New Jersey use cones in burning, but the majority do not. A number of cones were, therefore, distributed among the different fire-brick makers for placing in their kilns. From these. and those used regularly at some of the works it was found that the New Jersey fire-brick were usually burned at from cone 10 to cone 12. There is no reason to believe that those manufacturers whose kilns are not tested, burn at a much higher cone, although it is probable that in the hottest parts of the kiln a slightly higher cone may sometimes be melted. One manufacturer melted cone 16, by placing it opposite the opening from the hearth.

The absorption of the New Jersey fire bricks ranges in most cases between 11% and 14%. One sample of stiff mud maufacture showed 5.37%, but other stiff mud bricks ran as high as 13.00%.

Tests of New Jersey Fire Brick.—In order to test the refractoriness of the New Jersey fire-bricks and to determine its relation to their chemical composition and texture, samples of their different brands were requested from all the fire-brick manufacturers in the State. All except three readily agreed to the proposition and samples of the different brands were taken from the stock piles or kilns. The fusing point of the bricks was tested in the Deville furnace and a partial analysis made to determine the quantity of silica, alumina, ferric oxide, and titanium oxide, the balance being considered as lime, magnesia and alkalies.

These tests are tabulated in the accompanying table. The various samples are indicated by number, the name of the manufacturer not being published.

Each column is properly headed, and needs no explanation except, perhaps, the last two. The absorption represents the percentage of water absorbed by the brick when soaked for forty-eight hours, and is, therefore, an indication of its porosity. The column headed "Grade" represents the rank or quality of the brick as compared with others made at the same works. Thus all those marked No 1, come from different factories and represent in each case the best brick made at the factory from which they were taken. They are not always branded No. 1, for the best brick made at any one works may be marked XX, Special Al, or possibly something else. It will be seen from a comparison of those marked No. 1 that they vary in their refractoriness, from cone 33 down to cone 27.

Sample Number.	Constituents.					Cone of Fusion.	Absorption.	Grade.
	Silica.	Alumina.	Ferric Oxide.	Titanium.	Total.			
1	78.24	19.24	.68	1.66	99.82	33	13.39	1
2	82.45	14.86	1.54	.90	99.75	32	12.92	1
3	68.70	25.80	3.35	1.25	99.10	27	11.25	1
4	77.15	19.46	1.99	.95	99.55	27	14.33	1
5	75.20	21.09	1.37	1.72	99.38	33	12.72	1
6	81.10	15.81	2.19	.	99.10	27	13.92	1
7	68.90	28.21	.78	1.69	99.38	32	13.39	1
8	54.68	39.35	2.42	2.53	98.98	32		1
9	85.15	12.22	1.48	1.10	99.95	33		1
12	81.20	14.98	.92	1.43	98.53	30	11.90	2
13	72.37	24.67	.98	1.79	99.81	32	11.97	2
14	82.30	14.84	1.70	.71	99.55	31	12.48	2
15	74.10	21.72	1.37	1.91	99.10	32	11.70	2
16	84.99	13.20	1.75	....	99.94	30	13.39	2
18	78.84	18.06	.65	1.53	99.08	31		2
19	74.54	22.23	1.63	1.43	99.83	30		2
20	75.05	20.06	1.74	1.65	98.50	32	14.45	3
21	77.55	17.82	3.48	1.20	100.05	27		3
22	77.32	19.51	1.11	1.86	99.80	28-29	5.37	3
23	77.80	18.29	1.50	1.61	99.20	31	12.96	3
24	73.48	22.35	1.07	1.73	98.63	30		3
26	77.30	18.99	2.06	1.05	99.40	31-32	11.64	4
27	74.70	20.86	.98	1.62	98.16	28	11.42	4

An examination of the above table of analyses and fusion tests shows that the fusing points of the different bricks range from cone 27 to 33. It becomes of interest, therefore, to determine whether the same causes for these variations are operative here as were found to be active in the case of the fire clays. In other words, does the presence of a high percentage of both fluxes, and sand or free silica lower the refractoriness of the fire-brick?

If we compare the ratios of kaolinite to free silica we find that what has been said regarding the effect of silica on the refractoriness of a fire-clay also holds true in a very general way for fire-brick, but the relation here is not nearly so close. Thus, for example, No. 1 of the series would, if judged by its analysis, be expected to fuse not higher than cone 29 or 30, whereas, it actually

fuses about cone 33. If we examine the piece that was fused in the Deville furnace, we shall find that scattered through the fused mass there are white grains that seem to have resisted fusion, and an examination of the brick shows that probably 15% or 20% of it is composed of angular quartz grains, some of them one-sixteenth or one-eighth of an inch in diameter. We have, therefore, at once an explanation of the disagreement between the chemical analysis and the physical test, for it is well known that the size of grain exerts a strong influence on the fusing point of a clay.

Now, in this particular case, much of the silica is bound up in grains and fluxing action can only proceed from the surface of the grain inward, and, therefore, the ability of the brick to stand up under a high heat will depend to a large extent on the fusibility of the matrix in which these quartz grains are imbedded. If these latter were ground fine and evenly distributed throughout the brick, the latter might fuse at a lower temperature than it does at present.

For purposes of comparison a number of analysis and fusion points of foreign brick are given below, and it will be seen that those of high refractoriness run comparatively low in silica. Those having a fusion point similar to many of the New Jersey brick having in some cases a similar composition.

The writer regrets that he cannot give a table of fusion points of other American bricks for comparison, as very few have been published. Private tests show that they agree well with bricks from other states, except the better grades of Ohio and Pennsylvania brick, which fuse at cone 34 and 35.

(See table, page 147.)

Table of Analysis of Foreign Fire Bricks, together with their Fusibility.

	Name of Samples, etc.	Silica.	Alumina.	Ferric Oxide.	Lime.	Magnesia.	Potash.	Loss on Ignition.	Total Fluxes.	Cone of Fusion.
German Bricks	Marked A (Hecht, analyst)	51.15	45.72	0.80	1.77	....	0.34	0.28	2.91	35–36
	Marked B (Hecht, analyst)	57.55	40.56	1.36	....	0.97	....	0.56	2.33	—35
	Marked C (Hecht, analyst)	59.76	35.36	2.42	0.45	0.48	0.61	1.30	3.96	—35
	Marked D (Hecht, analyst)	58.84	38.71	1.20	0.30	0.20	0.74	0.33	2.44	34-35
	Marked E (Hecht, analyst)	50.00	46.21	1.62	0.55	0.35	1.21	0.12	3.73	35-36
	Palatina (Seger and Cremer)	54.28	42.52	1.92	....	....	....	....	4.20	—35
	Saarau, XXI	52.20	45.90	1.00	....	0.90	....	....	1.90	35-36
	Saarau, XX	52.50	43.60	1.60	....	2.30	....	....	3.90	34
	Saarau, A	62.50	35.30	1.60	....	0.60	....	....	2.20	33
	Saarau, O (Stolber, Prag.)	69.65	28.71	1.20	....	0.44	....	....	1.64	33
English Bricks	Walbottle	58.74	35.09	2.80	0.27	0.80	2.11	0.40	5.98	31-32
	Svan	58.02	36.84	2.64	0.45	0.52	1.54	0.22	5.15	31-32
	Preston Grange	58.50	31.41	6.00	0.70	0.64	2.41	0.50	9.75	28-29
	Lucas	61.24	30.48	3.20	0.45	0.54	3.90	0.54	8.09	—31
	Ramsay	58.41	32.80	4.94	0.40	tr	3.01	0.83	9.18	30-31
	Glenboig	62.06	32.81	4.34	....	0.83	....	....	5.13	30-31
	Glenboig	62.50	34.00	2.70	....	0.80	...	....	3.10	31
	Glenboig (sample from market)	58.58	34.13	4.22	....	3.07	....	....	7.29	30-31
	Stourbridge (Iron Jour.)	58.48	35.78	3.02	....	2.72	....	....	5.74	31-32
	Stourbridge	63.40	31.70	3.00	....	1.90	....	....	4.90	30-31

CHROME TIN PINK — A FURTHER DISCUSSION.

BY

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One of the most encouraging features of the work of this society is the fact that a subject, once introduced, is not easily lost sight of. Those who have given it attention contribute their results to the general stock of information, and the fund of facts grow steadily greater, our equipment more complete. And where can we find more conclusive proof of the sincerity and liberality of our members than in cases where the contributions stand for the accumulation of years of experience and of the expenditure of both effort and means which we are unable to estimate? For example, it is only necessary to refer to the articles in Vol. V, on the subject of the chromium tin pink.

Mr. Carter's valuable paper is both clear and consistent, and my purpose is not to discuss it critically, but to express his glaze batches in chemical formulae for the sake of a more convenient comparison with those quoted by the other observers.

Owing to the fact that the composition of both china clay and Cornwall stone vary in different samples, it cannot be claimed that the following formulae are exact representations of the glazes in question, but they will undoubtedly aid us in studying them:

TABLE OF FORMULAE OF CARTER'S GLAZES.

	PbO	$KNaO$	CaO	Al_2O_3	Cr_2O_3	SiO_2	B_2O_3	SnO_2
A	.819	.044	.134	.110	.0012	1.51	.000	.073
B	.658	.116	.221	.129	.0011	1.55	.163	.070
C	.510	.185	.301	.147	.0011	1.601	.316	.070
D	.369	.249	.379	.163	.0011	1.64	.458	.066
E	.238	.307	.448	.179	.0010	1.675	.590	.063
F	.117	.365	.516	.194	.0010	1.717	.718	.060
G	.000	.418	.581	.209	.0010	1.750	.836	.060

To quote Mr. Carter, "These were fired at cone 09, the results being as follows:

A. Rich mellow red, but rather too brown, hardly life enough, but still a beautiful color.

B. A little more red than A.

C. Beautiful bright crimson.

D. " " "

E. Good crimson but decided tint of purple.

F. A stronger tint of undesirable purple.

G. Disagreeable bluish purple color.

An inspection of this series reveals the following features:

Lime: The lime increases gradually throughout the series. The average lime-alkali ratio for the two best glazes is about 3:2.

Lead: Decreases regularly throughout the series.

Acidity: Both silica and boracic acid increase.

The observations of the report published in Vol. IV indicated that all these gradations, with the exception of the boracic acid, would be beneficial to the color. Since, in this case, they occur simultaneously, it is impossible to judge which are most active in affecting the glaze coloration.

It is readily seen, however, that Mr. Carter's glazes admit of the use of considerably more lead than previous reports have led us to believe it possible to employ. In this connection, it may be said that in the series given in Vol. IV, the effect of a high lead content was to produce somewhat puzzling, imperfect enamels, with a tendency to bead. As soon as a composition producing a perfect glaze was reached, the color was good. These observations, in the light of the formulae before us, and the fact that Mr. Hensel reports a fine pink glaze with 0.63 equivalent of lead, make it apparent that no lead limit can be assigned for general cases, and that the amount permissable depends, in part at least, upon other features of the glaze formula.

The general effect of boracic acid upon the color is evidently the same in all cases, the tendency toward purple being reported by all observers.

As to the mellowing effect of chromate of lead when added to "C" and "D," the question naturally arises, whether this improvement is due in part to the chromium or whether the

addition of lead in another form would have accomplished the same result. Mr. Carter refers to glaze "A," (the one highest in lead), as having the most mellow and artistic shade, and it is undoubtedly true that the lead in the chromate added to "C" and "D" is responsible for at least part of the mellowing effect. There is nothing upon which to base any conclusion as to the action of the chromium.

After all, the most interesting phase of Mr. Carter's work along this line is his experience with the green frit. No doubt all those who have experimented with chrome-tin colors have produced some green frits, and green glazes as well, but this is the only instance I have yet seen reported, in which the color has been converted back to the pink.

Understanding so little, if anything, of the constitution of the compound which gives us the pink coloration, it would be futile to discuss the subject theoretically. However, this report of Mr. Carter's may modify our opinions somewhat. Hitherto, it has been assumed that it is necessary to make a pink frit or stain, different in formula from the glaze employed and calcined separately. It is supposed that in this first fritting, a compound, presumably chromium stannate, is formed, which, though not destroyed by the glaze, may be modified by it. It has been observed that certain glazes, in which the pink color was preserved up to the temperature at which the glaze matured, would become green when fired to a higher temperature. In these cases it was supposed that the pink compound had been broken up, and would not form again. Here we have a case in which the whole glaze batch, including the previously fritted stain, was fritted together and came out green, but changed to pink when refired on the ware. If we assume that the pink compound introduced by the stain has been destroyed, we must conclude that a pink compound is afterward formed in the glaze itself. If this be true, why make a pink stain? Why not put the requisite amounts of chromium and tin into the glaze batch raw, melt to a green frit and use it on the ware as Mr. Carter did? Or for that matter, why not put the whole glaze on raw in the first place?

Mr. Hensel's report, introducing new methods of attack, under conditions different from those previously described, offers no contradictions to the previous reports. That the limits of

composition reported by him are somewhat narrow, may reasonably be attributed to the peculiarly trying conditions under which his glazes had to be burned. It seems probable, however, that in this case the color would be influenced by iron from the highly ferruginous body.

Mr. Purdy's paper, which is a discussion of the report of Vol. IV, calls for statements regarding several points which were neglected in that paper, some through oversight and others for the reason that explanations were regarded as superfluous.

Mr. Purdy's remarks advocating the use of various compounds of chromium and lime, apparently refer to the ingredients of the pink frit, and not at all to the glaze composition. He says in this connection that if fluorspar or gypsum were tried as sources of lime, or potassium bichromate, lead chromate or chromium sesquioxide as the sources of the chromium, a marked contradiction to the results obtained would have been found. However, not only lack of time, but lack of inclination as well, prevented the introduction of the compounds suggested. When these experiments were begun it was with the intention of striking at the essentials. Realizing that the investigation was to be limited, one would naturally endeavor to avoid encumbering it with complications. From Seger and the other investigators quoted, it was gathered that chromium and tin, or their oxides would produce colors, and that these colors would be affected by lime and silica. In the series of frit mixtures described, potassium bichromate was kept out in order to demonstrate that potassium is not an essential ingredient. Seger's formulae had already shown that lead is not required, so why use lead chromate? As for fluorides and sulphates, they would not logically come in until after the effects of magnesium, barium, strontium, etc. had been tried in the place of lime and titanic and other acids instead of silica. However, the work done up to this point indicates that if the pink stain is to be incorporated into a glaze, it is the best economy of time to use any good frit which can be produced with the equipment available, and devote ones attention to the glaze itself.

The statement that a high temperature is required to develop the color of the pink stain is evidently not true of all formulae. With most of my stains, containing only tin and chromium, or

tin chromium and lime, or these three with silica, temperatures considerably above those which would melt some of Seger's frits and those of Hensel, are required.

Mr. Purdy next objects to the use of chromic acid on the ground that, as far as he knows, potters never use it. But is the use of an unusual agent to prove a point in course of research, an objectionable feature of the research? Must we always confine ourselves to those substances already in common use? But Mr. Purdy says of this compound that "its end reaction on the other ingredients cannot be the same as that of the other chrome compounds." This cannot be contradicted, for nobody has yet been able to show what this end reaction is, if indeed there be any. However, if one ingredient helps to produce one so-called "end reaction," and a second compound produces *something* of which the color is as good as the first, why should we not use the latter if convenient?

Attention is next called to an oversight in my description of the manufacture of the pink stains. It should be stated that the frits used in the various series of glazes were calcined a second time after an intermediate washing and grinding. After the second calcination, they were ground wet and the water decanted off, thus effecting another washing. The frit becomes brighter with the calcination. In the frits which were members of the *frit* series, there are no ingredients which would be soluble after calcination. These were burned but once, and the glaze colors produced with them were as good as those with the twice calcined frits.

The one "sweeping conclusion" which it is justifiable to draw in this connection is that, although all the work done on the subject has been carefully and studiously carried out, we cannot expect the results obtained by one investigation to tally precisely with those of another, using glazes of a different type and working with different materials under different conditions.

Discussion.

Mr. Burt: I would like to ask whether Mr. Hull has tried putting the chrome-tin ingredients in the raw glaze, with the idea of getting the color that way?

Mr. Hull: Unfortunately, since the paper of Mr. Carter came out, it has been impossible for me to do anything along that line.

Mr. Hottinger: I had that occur by accident. I was using a tin enamel, and grinding a minute part of chromate of iron with it; so it indicates that the color does not need to be made in advance, but may be produced in the glaze.

Professor Binns: I had an experience along a similar line. I rather encourage my students to come to me with problems, and one young woman came to me with a flower and asked if I could make that color in a glaze. I said I thought I could. I made two trials. The color was a peculiar light brownish-salmon, a very pleasing tint. I made a mixture in matt glaze, thinking I could produce it with tin chrome pink modified by iron. I introduced potassium chromate, tin oxide, and oxide of iron, and thereby got a very pleasing brownish-pink tint.

I had another experience with tin-chrome pink. I was burning a kiln in which were some pink glazes, and reduction occurred, bleaching the pink. It produced a dirty gray, not a pleasing or satisfactory color at all—a pale, drab color. This occurred on two pieces of ware, one of which was entirely changed, and in the other one side retained the pink, an effect which I never produced before and do not think I could again. The other piece I wanted to change, so dipped it in a blue glaze, fired again, and the pink came back, showing through the blue and giving a purple result. It shows that pink is very susceptible to reduction action, and is readily restored by re-oxidation.

Mr. Burt: In Berlin I was firing color in a gas kiln. I put the crucible down with the color in it, and above put a cone—I think cone three. It was not lower than that: it had no iron in it. The cone went down and I shut off the fire, and when I drew the kiln, here was the cone a beautiful pink color all over. Did that color volatilize and settle there on this perfectly pure white cone as a compound? I do not think so. I think the elements had to volatilize separately, and when the Cr_2O_3 and tin and lime met on the surface of the cone, the color was formed.

Mr. Watts: Mr. Hull, do these formulae (referring to Carter's) come within the limits of your other paper? Do they

come within the same range which you outlined in your former paper?

Mr. Hull: As I noted in this last discussion, the lead runs higher here than I have ever seen it reported before.

Mr. Watts: In other respects it is about the same?

Mr. Hull: In other respects it checks the other very closely.

Mr. Watts: About two months ago I met an old friend, and we naturally took up a discussion of various ceramic topics. He was reciting to me a chrome-pink formula and showing me some samples; and I notice that this fromula which I have in my note book is within reasonable range of your sample "B," except that yours is twelve hundredths of alumina instead of thirteen. But he has 0.005 of chromium and uses 0.17 of tin; and his colors are fine, gotten at cone nine. He uses 0.64 lead in his glaze. I happen to have this memorandum with me, and it occurs to me to see where it comes. This is as brilliant a red as I ever saw from a chrome tin compound. I believe you said this "B" here is rather inferior?

Mr. Hull: It is very good, but required quite exact firing.

Mr. Watts: I think you can account, to a certain extent, for this rise in quality of the red in "C" and "D" samples, and the falling off in "E," "F," and "G," by the fact that you are reaching about the point where you get the best results in chrome tints, and beyond that they are not so good. While in the other case, your silica is increased, and you naturally get superior results in chrome tin colors as your silica increases.

NOTES ON CEMENT.*

BY

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A. THE LIMITS OF FREE SILICA AND CALCIUM OXIDE ALLOWABLE IN PORTLAND CEMENTS WHICH ARE MANUFACTURED BY THE DRY PROCESS.

In the manufacture of Portland cement, we are dealing with three distinct processes of manufacture based on the character of three classes of available cement materials, namely,

Marl and clay.
Cement rock and limestone.
Limestone and clay.

The first, marl, is available usually in the wet condition, containing often 20 per cent. of water, or being, as is often the case, dredged from the bottom of lakes. The wet method of grinding this kind of cement material is hence obvious, and has been adopted as the prevailing mode of preparation.

The second class of materials are the hydraulic cement rocks of the Lehigh Valley, Pennsylvania, which contain almost the proper amount of clay base for the Portland cement composition, and which need only some additional lime which is added in the shape of limestone. These hard, rock-like materials naturally are adapted for the dry grinding process.

The same thing applies to the limestones, low in clay, to which clay must be added for the production of Portland cement. This combination is the kind of cement materials available in Ohio, and hence deserves special study. The questions which arise naturally in discussing the composition of these cements depend mainly on the mineral character of the cement raw materials. This includes the question of the crystalline character of calcium carbonate, the density and hardness of the rock, and the mineral character of the clay used, together with the general physical

* Published in advance, by permission of Prof. Edward Orton, Jr., State Geologist, from Bulletin 3, Series IV, Geological Survey of Ohio.

properties of the latter, which depend on whether it is a soft clay or a hard shale, an alluvial or glacial clay.

The harder and more crystalline the calcium carbonate is, the more reluctantly will it combine with the silica of the clay. For instance, Rebuffat has found in the examination of certain natural cements that amorphous calcium carbonate would react with silica at low temperatures at which the crystalline carbonate absolutely refused to combine. Again the difference in the kind of crystallization is an important factor, in regard to which point we have as an illustration calcite and arragonite, crystallizing in the hexagonal and rhombic systems respectively. Though both are calcium carbonate, and on expelling carbon dioxide produce calcium oxide, the calcite furnishes an oxide which hydrates with the evolution of heat and slakes with an increase in volume, while the arragonite slakes with difficulty and forms needle like crystals of calcium hydrate without increase in volume.

In the clay base, extreme variations are liable to occur in regard to the mineral composition, and especially in regard to the ratio of the combined to the free silica. Combined silica from clay substance unites with calcium oxide with great ease, but free silica is available only if ground very fine, and then it reacts at a temperature much higher than that required for the union of combined silica. As far as the silica content is concerned, pure clay substance, or kaolin, would furnish the most easily assimilated silica. But there is this great draw back: Clay substance introduces beside silica a large amount of alumina, which, though producing additional hydraulicity in the cement, brings in a great element of weakness in regard to the constancy in volume; it causes the cement to set very rapidly, and after a time to swell and disintegrate. Therefore, though a certain amount of clay substance is desirable, it must not run too high. The question of the balance between combined and free silica becomes hence a delicate one. Free silica is reluctant to combine with calcium oxide, and is liable to give trouble because of the imperfect union; combined silica obtained from clay substance unites readily with lime, but brings in too much alumina.

Certain localities, like the lake regions of Michigan, Indiana and Northern Ohio, are rich in peculiar deposits, extremely

fine in grain, which are redeposited drift clays or lacustral clays, like the Albany slip, or the Millburg, Ohio, clays. These regions, possessing such clays together with extremely fine grained marls offer an almost ideal combination, amorphous calcium carbonate and fine grained clays, quite low in clay substance.

In the second mixture of raw materials, clayey limestones and limestone low in clay, we have as the main constituent a limestone high in clay, but extremely fine in grain, blended together in the most intimate mixture possible by natural processes. All that is necessary is to grind in enough lime to bring in the calcium content required for Portland cement.

The greatest difficulty comes in the third mixture, consisting of limestone and clay. Ordinarily the limestones are more or less well defined crystalline masses, and the clays available vary through all types, from fire clays down to the alluvial deposits. The question now is to select the proper clay, that is, one having the correct ratio between combined and free silica, and also one which contains this free silica in the finest grained condition, so as to save the expense and time otherwise required to grind it to the required fineness. This clay is now to be combined with the lime in a ratio approaching as the limit the chemical composition $x\ (3\ CaO\ S:O_2) + y\ (2\ CaO\ Al_2O_3)$. That is, for every part by weight of silica, 5 parts of calcium carbonate is to be brought in, and for every part of alumina, 2 parts of calcium carbonate. But this theoretical limit cannot as a rule be reached, since in the process of manufacture it is impossible to give the materials the thorough grinding necessary to produce molecular contact. Insufficient grinding and the maximum lime content result in a cement containing uncombined lime, which on slaking expands and destroys the cement. We are hence compelled to ask, if the limit $(3\ CaO)\ SiO_2\ (2\ CaO)\ Al_2O_3$ cannot be reached, what composition must be accepted as proper. This question is justified the more, since the grinding of the limestone and clay is done in the dry way which, as is well known, does not bring about such an intimate blending as the wet process.

The Problem Defined.

We are hence dealing with these two questions:

1. What should be the ratio between the combined and free silica in the clay base?

2. What molecular ratio of lime should be accepted for blending in the dry way?

These questions are of importance to Ohio manufacturers of Portland cement, inasmuch as the future development of the Ohio cement industry depends on the use of limestone and clay, manufactured into cement in the great coal district of Southern and Eastern Ohio. The writer has attempted to answer the questions by a series of experiments, which were carried out as follows:

Batches of cement mixtures consisting of kaolin, potters' flint and whiting were prepared, with sufficient ferric oxide in the form of red Clinton iron ore, to give to all the cements a content of about 3% of ferric oxide. These batches were ground in an iron ball mill for four hours, making from twenty to thirty pounds of each cement, and after grinding were mixed up with water into a plastic mass, which was cut up into rough cubes, and then dried. The dry mix was burnt and cooled rapidly, as soon as vitrified. The iron content acted, so to speak, as an indicator, causing the degree of vitrification to become well-marked. The cements high in calcium oxide were burnt in a small cylinder furnace lined with a mixture of magnesite and Portland cement, and fired with gasoline gas. The mixtures low in calcium oxide were burnt in an up-draft kiln. No attempt was made to measure the temperature in the cylinder furnace, owing to the difficulty of introducing the thermocouple. In the up draft kiln, it was measured by means of the Chatelier pyrometer. According to the basicity of the cements, the temperature ranged from 1270 to 1400° C.

The clinker produced was carefully assorted and all inferior pieces rejected. The selected clinker, which usually showed wherever the composition was suitable, the characteristic black color and the glittering particles so well known to the cement man, was ground and screened through a 100 mesh sieve. This cement powder was then made up into briquettes, 1 cement: 3 standard sand, placed in moist air till hard enough to be immersed in water, where they remained for 28 days. They were then tested for tensile strength in a Fairbanks testing machine. Another portion of the neat cement was made up into pats, kept in moist air for from 12 to 24 hours, and in water for 24 hours,

when they were boiled in water for six hours to test them for constancy in volume, that is, their tendency to crack and warp, or their liability to break down to a soft mass.

The chemical composition of the series was arranged to vary from the maximum content of lime (3 CaO) SiO_2 (2 CaO) Al_2O_3, down to (2.6 CaO) SiO_2 (2 CaO) Al_2O_3, making 5 groups of cements, with the following scale of composition:

1. (3 CaO) SiO_2, (2 CaO) Al_2O_3.
2. (2.9 CaO) SiO_2, (2 CaO) Al_2O_3
3. (2.8 CaO) SiO_2, (2 CaO) Al_2O_3
4. (2.7 CaO) SiO_2, (2 CaO) Al_2O_3
5. (2.6 CaO) SiO_2, (2 CaO) Al_2O_3

At the same time another series was incorporated by allowing the clay substance and the free silica to vary in the mixture. Owing to the fact that even dried kaolin caused some of the mixture to stick to some extent to the pebbles of the ball mill used in grinding, dehydrated kaolin was used which had been heated just enough to expell all of the water of hydration.

The clay base was introduced in five variations:

1. Kaolin dehydrated; silica—alumina ratio, that is. percent silica divided by percent alumina, 1.16:1.

2. Kaolin and flint mixture; ratio of combined to free silica 1 : 1.58; ratio of silica to alumina 1.86 : 1.

3. Kaolin and flint mixture; ratio of combined to free silica, 1 : 1.99; ratio of silica to alumina 2.33 : 1.

4. Kaolin and flint mixture; ratio of combined to free silica 1 : 2.56; ratio of silica to alumina, 3 : 1.

5. Kaolin and flint mixture; ratio combined to free silica 1 : 3.41; silica alumina ratio 4 : 1.

In the following table the results are arranged in this order. The fact that the tensile strengths of these cements do not average higher is due to the fact that the clinker was not ground very fine. All of the cement passed the 100 mesh sieve, but the percentage of the finest dust produced was comparatively low.

No.	Formula of Cement	Clay Base		Appearance of Clinker	Tensile Stre'g'h 1:3 after 28 days Pounds per square inch	Boiling Test
		Ratio between Combined and Free Silica.	Ratio between Silica and Alumina.			
1	$3\ CaO\ SiO_2$ / $2\ CaO\ Al_2O_3$	1:0	1.16:1	yellowish	49	poor
2	do	1:1.58	1.86:1	slightly yellow	187	poor
3	do	1:1 99	2.33:1	good clinker	180	fair
4	do	1:2.56	3.01:1	good clinker	187	fair
5	do	1:3 41	4.00:1	good clinker	203	poor
6	$2.9\ CaO\ SiO_2$ / $2\ CaO\ Al_2O_3$	1:0	1.16:1	brown slag	..	poor
7	do	1:1.58	1.86:1	slightly brown	193	poor
8	do	1:1.99	2 33:1	good	168	fair
9	do	1:2.56	3 01:1	good	232	stood test
10	do	1:3 41	4.04:1	good	230	good
11	$2.8\ CaO\ SiO_2$ / $2\ CaO\ Al_2O_3$	1:0	1.16:1	slag like	109	poor
12	do	1:1.58	1.86:1	good	228	poor
13	do	1:1.99	2.33:1	good	305	good
14	do	1:2.56	3.00:1	good	221	good
15	do	1:3.41	4.01:1	good	188	good
16	$2.7\ CaO\ SiO_2$ / $2\ CaO\ Al_2O_3$	1:0	1.16:1	tendency to dust	30	poor
17	do	1:1.58	1.86:1	fairly good	102	poor
18	do	1:1.99	2.33:1	good	67	poor
19	do	1:2.56	3.00:1	good	150	good
20	do	1:3.41	4 01:1	good	225	good
21	$2.6\ CaO\ SiO_2$ / $2\ CaO\ Al_2O_3$	1:0	1.16:1	dusted	66	poor
22	do	1:1.58	1.86:1	dusted	71	poor
23	do	1:1.99	2.33:1	dusted	102	fair
24	do	1:2.56	3.01:1	dusted in part	82	poor
25	do	1:3 41	4.00:1	good	113	good

In considering these results. it must be remembered that the cements with a highly silicous clay base harden much slower than more aluminous cements, taking several months to show their real tensile strength, which, however, is very high.

Conclusions.

1. These experiments show conclusively that the ratio of combined to free silica, or of silica to alumina, is of vital importance. Where all of the silica is brought in as combined silica, the resulting cement is worthless. The best ratio of combined to free silica is 1:2.56, and the best silica-alumina ratio is 3:1.

2. The lime-silica ratio to be used depends, of course, largely on the fineness of dry grinding, which in these experiments was carried beyond the commercial limit. From the facts brought out in these and other experiments, it seems quite well established that the ratio best suited for dry ground mixtures, with a silica-alumina ratio of 3:1. the best formula is (2.8 CaO, SiO_2) (2 CaO, Al_2O_3).

This was further confirmed by tests made with a silicous clay found on the campus of the Ohio State University, and a hard limestone, from near Wellston, Ohio.

The analysis of the clay was:

	Percent
Silica	68.80
Alumina	14.71
Ferric Oxide	4.50
Calcium Oxide	2.79
Magnesia	2.49

Ratio silica to alumina: 4.67:1.

The composition of the limestone was:

	Percent
Calcium Carbonate	91.82
Silica	3.52
Alumina and Ferric Oxide	3.51
Magnesium Carbonate	0.63

The tests of the cements produced from these materials showed the following results:

Formula	Tensile Strength 1:3, 28 days Pounds per square inch.	Boiling Test
(2.9 CaO SiO_2) (2 CaO Al_2O_3)	290	good
(2.8 CaO SiO_2) (2 CaO Al_2O_3)	360	good
(2.7 CaO SiO_2) (2 CaO Al_2O_3)	190	good, but off glass

These clinkers were ground finer than those of the preceding series, having been ground in a ball mill.

B. THE EFFECT OF CALCIUM HYDRATE UPON NATURAL CEMENTS.

A study of the composition of the American natural cements reveals the fact that they show extreme variations in composition, from near the bi-calcium silicate down to the mono-calcium silicate. This absence of uniformity has led the writer to consider their hydraulic activity as being due to a kind of pozzuolanic reaction; that is, the calcium oxide produced on burning simply renders the silica of the silicious matter "soluble," producing an active silicic acid, which combines with the lime to form a high acid compound, with the ability to combine with more lime. This lime ought to react with the silica even at ordinary temperatures if brought in as calcium hydrate, and hence the addition of dry slaked lime should prove whether the hydraulic reaction is pozzuolanic in character or not.

In order to investigate this matter experimentally, four samples of natural cement rock were taken, representing the Rosendale, Louisville and Utica districts, and burnt in lumps till practically all carbon dioxide was expelled. They were then ground in a ball mill in two portions. To one five per cent. of dry slaked lime was added; the other was ground without any additions. The lime was prepared by shaking with excess of water, and drying till practically all mechanical water was expelled.

In the following table the results of this test are compiled:

No.	Description	Tensile Strength 1:1, 28 days Pounds per sq inch	Remarks	Gain in Tensile Strength in Percent
1	Rock alone.....	94	probably over burnt	.....
1	Rock+5% slaked lime	...	broke in 2 days	.....
2	Rock alone.....	...	checked and swollen	.....
2	Rock+5% slaked lime	230	sound	70.4
3	Rock alone.....	135	sound	.....
3	Rock+5% slaked lime	200	sound	44.4
4	Rock alone.....	100	sound	.....
4	Rock+5% slaked lime	270	sound	170.0

The conclusion which must be reached is that the reaction appears to be decidedly pozzuolanic in character as the addition of five per cent. of lime hydrate to these natural contents, with the exception of rock No. 1 which was probably overburnt, showed a most decided improvement in tensile strength. From the practical standpoint this should prove valuable to natural cement manufacturers as this small amount of dried, slaked lime should not increase the cost of manufacture appreciably considering the gain in strength.

At the same time, two students of the Civil Engineering department of the Ohio State University, H. B. Nichole and R. E. Hamilton, conducted experiments with cement mortars, to which varying amounts of lime paste were added. Their results were as follows:

Mixture	Tensile Strength after 26 weeks 1:2. Pounds per sq. inch	Gain in Percent
Natural Cement.....	292	
96% cement+ 4% lime.....	335	14.7
92% cement+ 8% lime.....	325	11.4
90% cement+10% lime.....	325	11.4
85% cement+15% lime.....	322	10.4
80% cement+20% lime.....	357	22.3
75% cement+25% lime.....	304	4.1

These experimentors also added lime paste to Portland cement mortar, the brand used being a standard American cement, but it was found that the strength began to decrease at once, as was to be expected. Portland cement being already a subsilicate has no need of further additions of lime in any form.

It also appears that the addition of dried calcium hydrate in the grinding of the natural cement is much to be preferred, as the results are more strikingly favorable.

C. A STUDY OF THE GRINDING PROCESS OF QUARTZ SAND IN TUBE MILLS.

Since in various branches of the silicate industries the grinding of quartz sand is a necessary operation, it was thought advisable by the writer to study the progress of grinding quartz by making mechanical analyses at various stages of the disintegration. The experiment was carried out in a chilled iron ball mill, having the shape of a flattened sphere, with a diameter of 24 inches, and a width, at the center, of 7¾ inches; in this was placed 126 pounds of flint pebbles and 25 pounds of quartz sand. The same machine accomplished the grinding of a limestone-clay Portland cement mixture in four hours, reducing the cement to a fineness where everything passed a 100 mesh sieve, the charge being also 25 pounds. The cement mixture on ignition left no insoluble residue in acid and sodium carbonate solutions.

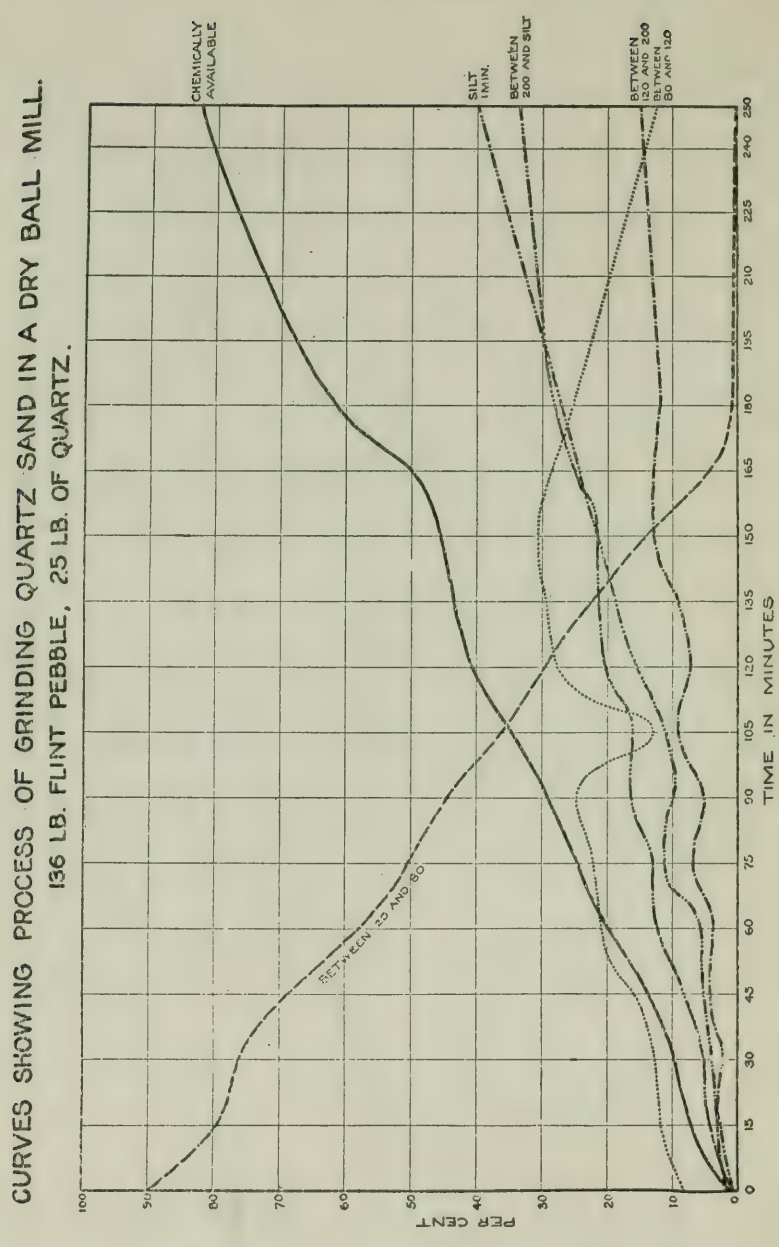
It would be, of course, absurd to draw from this experiment any conclusion whatever in regard to the general efficiency of ball mills, but it is thought that it will show the relative fineness produced by grinding the quartz sand the same length of time as

is required to reduce a practical Portland cement mixture to the desired fineness. The problem gains in practical value owing to the fact that numerous Portland cement works could improve the quality of their output by grinding sandstone into their mixture. But as the stone could not be reduced fine enough in the complete mixture, that is, surrounded by the softer particles of clay and limestone, it must be given two grindings, one preliminary to mixing and the second while a component of the completed mix.

The experiment would seem to indicate that quartz sand, from the intermediate grinders, that is, from the ball or Kent mill, would have to be ground longer in the tube mill than a mixture composed of hard limestone and soft clay. The time of grinding of the quartz would be to the time of grinding the mixture as 5:4. That is, if in tube mills of the same size and speed, the mixture passes through at the rate of 20 minutes, the sand would have to remain in the mill 25 minutes, the weights of substance ground being equal.

The criterion by which the fineness of the sand is estimated is the amount of chemically available material, that is, the sand which when mixed with lime in the proportion used in Portland cement and ignited, becomes soluble in hydrochloric acid and sodium carbonate solutions. Or in other words, the sand which may become available in cement reaction.

The results of the experiment are shown in the accompanying curve, and need no further explanation:


CURVES SHOWING PROCESS OF GRINDING QUARTZ SAND IN A DRY BALL MILL.
136 LB. FLINT PEBBLE, 2.5 LB. OF QUARTZ.
CHEMICALLY AVAILABLE
SILT 1MIN.
BETWEEN 200 AND SILT
BETWEEN 120 AND 200
BETWEEN 80 AND 120
BETWEEN 2.5 AND 80
PER CENT
TIME IN MINUTES
0
10
20
30
40
50
60
70
80
90
100
0
15
30
45
60
75
90
105
120
135
150
165
180
195
210
225
240
250

CERAMIC SHORTHAND

BY

EDWARD C. STOVER, Trenton, N. J.

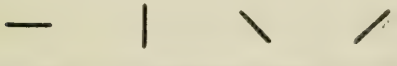
In these busy days, time is really one of our most precious factors. One who is constantly figuring ceramic problems gets weary of repeatedly writing Al_2O_3 and SiO_2, etc. I frequently thought how convenient it would be if the above could only be accurately expressed by "-" and "." instead of using five letters and figures for first, and four letters and figures to express the latter.

After much thought and numerous trials I have adopted a system of characters, very simple in form, easily made and read, to express the forty-five (45) substances most frequently used in ceramics, that are given in the "Manual of Ceramic Calculations," issued in 1900 by The American Ceramic Society.

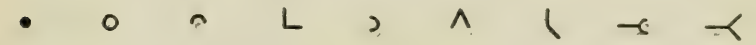
I feel it is necessary to make a few explanations. The universally adopted letters and figures for expressing all chemical formulae is so complete, so accurate, and so comprehensive the world over, that I would not think of even suggesting a single change in it for our ceramic literature, or where examples, problems, etc. are to be communicated from one person to another.

My new system of "Ceramic Shorthand," so to speak, is only intended for individual use, where economy of space and time are factors.

In making my groups, and prefixes and suffixes, I have done so from a Potter's view-point, rather than from a scientific one, as I found that even Mendelejeff's eight groups by oxygen ratios, 12 series by the attomic weights, in his celebrated "Periodic Law" tables would not suit our purpose, which can readily be seen below:



The horizontal, perpendicular, down slant and up slant straight lines form the main body of all characters used, to which are added



as prefixes and suffixes, and according to where and how they are added the individual materials are designated. Anyone familiar with Ceramic Technology will appreciate the grouping. The characters for each group are similar for convenience to learn and to remember.

GROUP I.

	Chemical Formula	Equivalent Weight	Shorthand Character
A—Flint, Sand, Silica, and the Silicates	SiO_2	60	
B—Alumina	Al_2O_3	102	
C—Kaolin, American	Al_2O_3 2 SiO_2	258	
D—Ball Clay, American	Al_2O_3 2 SiO_2	258	
E—Kaolin, English	Al_2O_3 2 SiO_2	258	
F—Ball Clay, English	Al_2O_3 2 SiO_2	258	

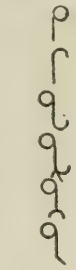
GROUP II.

A—Feldspar, Orthoclase or "Potash Spar"	K_2O Al_2O_3 6 SiO_2	557	
B—Feldspar, Albite, or "Soda Spar"	Na_2O Al_2O_3 6 SiO_2	524	
C—Feldspar, Oligoclase, or "Lime Soda Spar"	(CaO Na_2O) Al_2O_3 5 SiO_2	520	
D—Feldspar, Potash Soda Spar	(K_2O Na_2O) Al_2O_3 6 SiO_2	525	
E—Cornwall Stone	K_2O 2, 5 Al_2O_3 20 SiO_2	1550	
F—Cryolite	$Na_3Al\ F_6$	420	

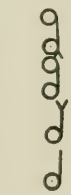
GROUP III.

A—Lead, Litharge	PbO	222	
B—Lead, Red	Pb_3O_4	228	
C—Lead, White	2 ($PbCO_3$), $Pb(OH)_2$	258	
D—Zinc Oxide	ZnO	81	
E—Tin Oxide	SnO_2	149	

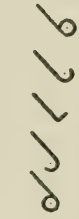
GROUP IV.

	Chemical Formula	Equivalent Weight	Shorthand Character
A—Potash	K_2O	94	
B—Pearl Ash	K_2CO_3	138	
C—Soda Ash	Na_2CO_3	106	
D—Soda Crystals	Na_2CO_3 $10H_2O$	286	
E—Sodium Chloride Common Salt	Na Cl	116	
F—Sodium Nitrate	Na NO_3	170	

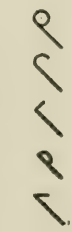
GROUP V.

A—Borax Crystals	Na_2O $2(B_2O_3)$ 10 (H_2O)	382	
B—Borax Calcined	Na_2O $2(B_2O_3)$	202	
C—Boric Acid, Flaky	B_2O_3 3 H_2O	124	
D—Boric Acid, Calcined	B_2O_3	70	

GROUP VI.

A—Antimony	Sb_2O_3	288	
B—Baryta	$BaCO_3$	197	
C—Barium Sulphate "Heavy Spar"	$BaSO_4$	233	
D—Magnesium Carbonate	$MgCO_3$	84	
E—Magnesium Oxide	MgO	40	

GROUP VII.

A—Lime, "Quick Lime"	CaO	56	
B—Whiting, Marble	$CaCO_3$	100	
C—Plaster Paris, Gypsum	$CaSO_4$ 2 H_2O	172	
D—Bone—Bone Ash	Ca_3 $(PO_4)2$	103	
E—Fluorspar	CaF_2	78	

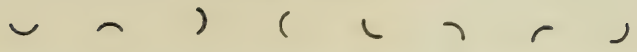
GROUP VIII.

	Chemical Formula	Equivalent Weight	Shorthand Character
A—Chromium Oxide	Cr_2O_3	152	
B—Cobalt Oxide	Co_3O_4	80	
C—Copper Oxide	CuO	79	
D—Iron Oxide	Fe_2O_3	160	
E—Manganese Oxide	MnO_2	87	
F—Nickel Oxide	NiO	75	
G—Uranium Oxide	U_3O_4	523	
H—Tin Chromium Pink	SnO_2, Cr_2O_3, CaO	———	

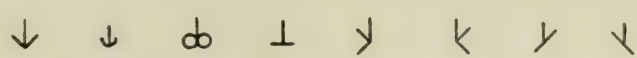
PREFIXES AND SUFFIXES.

A—Flint, Sand, Silica, and the Silicates	
B—Oxygen and Oxides	
C—Carbon and Carbonates	
D—Sulphur and Sulphates	
E—Phosphorus and Phosphates	
F—Fluorine and Fluorides	
G—Nitrogen and Nitrates	
H—Chlorine and Chlorides	
I—Water, H_2O	
J—Fritt	
K—RO	
L—R_2O_3	

In the event of further additions or more definite modifications being desired, the following curved single strokes are available:



All would be subject to the same prefixes and suffixes, and if additional of the latter are wanted, the following simple ones are available:



The horizontal dash— is used exclusively in Groups I and III, the additions being above the line in the former, and under the line in the latter.

Group II is of necessity made of compound characters, the proper units representing the elements being employed. Feldspar and Cornwall Stone are distinguished by the extra silica dot in the latter, which has the larger silica contents.

Groups VI and VII are both down slant lines. the former having the additions at the bottom, the latter at the top.

Group VIII are up slant lines, except Tin Pink, which is a compound character.

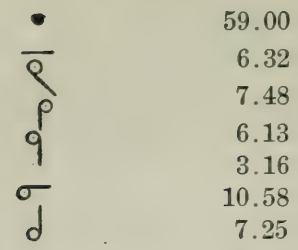
Groups IV and V are the vertical lines with the necessary endings, the latter containing boric acid compounds.

Examples of the Use of the System:

From the Manual of Ceramic Calculations, page 213, take the analysis:

Silica	59.00
Alumina	6.32
Lime	7.48
Potash	6.13
Soda	3.16
Lead Oxide	10.58
Boracic Acid....	7.25
47 letters,	99.92

It requires 47 characters, besides the figures, to write the above analysis. Written by the proposed shorthand system, it is:



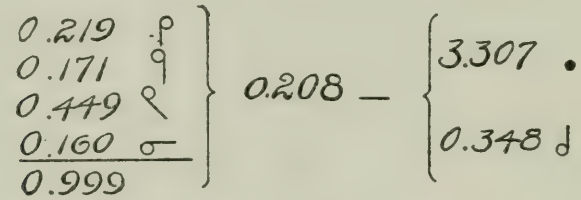
	59.00
	6.32
	7.48
	6.13
	3.16
	10.58
	7.25
	99.92

Which requires only seven characters to do the same work.

For another case, take the formula on page 214:

$$\left.\begin{array}{l} 0.219\ K_2O \\ 0.171\ Na_2O \\ 0.449\ CaO \\ 0.160\ PbO \\ \hline 0.999\ RO \end{array}\right\} 0.208\ Al_2O_2 \left\{\begin{array}{l} 3.307\ SiO_2 \\ \\ 0.348\ B_2O_3 \end{array}\right.$$

Which requires 25 characters beside the figures denoting quantity. Written by my system, this formula becomes:



requiring 7 simple characters, beside the figures.

EXPERIMENTS WITH FINE GRINDING OF FLINT AND SPAR.

BY

JUNIUS F. KREHBIEL, B. Sc., Delevan, N. Y.

A THESIS PRESENTED FOR GRADUATION, IN JUNE, 1904.
NEW YORK STATE SCHOOL OF CLAYWORKING AND CERAMICS,
ALFRED, N. Y.

The field covered by the influence of flint and spar in pottery bodies, especially vitreous ones, is very large and is susceptible of treatment along different lines either in a purely chemical way, or in a mechanical way, as it will be considered in this paper.

Silica or quartz is used in pottery bodies either for opening the body, in which case it is used in grains of varying size, and the bodies are not fired so high but what the quartz remains as such and the body more or less porous, or it may be used in the vitreous mass to combine more fully with the fluxing material and form new compositions more readily than will the less fusible kaolinite. The use of feldspar in pottery bodies is not to give them shape, but strength, for at the temperature at which it is used as a flux it becomes fluid, and by dissolving or combining with the more refractory materials to a greater or less degree it produces a dense mass, with translucency according to the purity and proportion of materials used.

Flint and spar occupy so important a place in the construction of bodies in which they constitute about half, and since they are not given to us in a finely divided state as in clay, but in the form of hard rock which is pulverized with difficulty, a wide field for research presents itself both in the pulverizing of the rock, and in its effects when mixed with clay. This embodies the finding of the effects of the different degrees of fineness, the proper grinding for these two materials, the establishment of a standard of fineness, and a sure, quick, and easy method of testing.

A considerable amount of material is at hand, by different authors on different parts of the subject, and to be more

familiar with some of the points already made, a summary of these articles will follow.

Seger gives some valuable information concerning the hardening or maturing of clay wares.

"By the condition of being matured we understand that condition in which by the effect of heat some of its constituents have been so far melted that they are able to cement the parts not melted, without destroying the porous character and producing noticeable changes of form by too great softening. If the liquifaction be increased or long continued, the influence of heat goes so far that a sufficient amount of a vitreous mass is present to fill the pores of the clay, and at the same time to produce a material softening. The process of firing to a matured condition has for its purpose the formation of a small amount of liquid substance, which physically and chemically we are wont to call glass. This strengthening binding material, whose chemical nature is indifferent for our purpose and may be subject to the greatest variations, is formed in part by the melting of fusible compounds already in the clay; in part it is the result of a chemical process which takes place during the burning, which must, however, never be very extensive if the earthy character of the clay is to be retained. The degree of heat necessary to produce that degree of fusion in the clay to furnish the liquid binding material becoming solid with the decreasing temperature, for those parts not affected by the heat, is in the first place dependent on the chemical nature of the materials, but also on the distribution of the physical properties of the individual components, especially of the rock dust and sand which in general are the only components quantitatively to be considered, in which there has been preserved during the process of weathering a part of the crystalline structure."

From a paper by Mr. W. Jackson, A. R. C. S., under date of October 11, 1902, it is found that Mr. Jackson experimented with flint ground in cylinders and that ground in pan, elutriating samples of each and examining as to shape. He found the shape of the flint grains to be the same in both cases; very angular, showing the grinding in either case to be a series of fractures.

A year later the following article appeared in substance. In the article Mr. Jackson first makes note of the fact that chemical action takes place between substances when their surfaces are in contact, and then says:

"It will follow that the greater the surface of reacting substances the more rapid and complete will be the chemical changes produced. Since more chemical action is necessary in vitreous wares, glasses and fritts than in porous bodies, it is necessary to have as great a surface as possible exposed in order to produce results quicker and at lower

temperatures, and this is done by fine grinding. But this is not all, for the same surface area must occur in all grinds in order to produce the same results. The following is the mathematical explanation of the relation of the diameter of grains to surface area, assuming the grains to be spheres or nearly so.

Let D and d be the diameter of the two spherical particles.

Their volumes are respectively

$$\frac{3.1416D^3}{6} \text{ and } \frac{3.1416d^3}{6}$$

and if G is the specific gravity, their masses are

$$\frac{G\,3.1416\,D^3}{6} \text{ and } \frac{G\,3.1416\,d^3}{6}$$

And in the unit there will be

$$\frac{6}{G\,3.1416\,D^3} \text{ and } \frac{6}{G\,3.1416\,d^3}$$

particles. Now the surfaces of particles with diameters D and d are $3.1416D^2$ and $3.1416d^2$ respectively, and hence the surfaces for unit mass of particles having diameters D and d are

$$\frac{6}{G\,3.1416\,D^3} \times 3.1416D^2 = \frac{6}{G\,D} \text{ and}$$

$$\frac{6}{G\,3.1416\,d^3} \times 3.1416d^2 = \frac{6}{G\,d}$$

Therefore the ratio of the surfaces is

$$\frac{6}{G\,D} : \frac{6}{G\,d} :: \frac{1}{D} : \frac{1}{d}$$

or, the surfaces vary inversely as the diameters."

He then gives a table of samples of flint elutriated by means of Schoene's elutriation apparatus into the sizes 0-0.01mm., 0.01-0.025mm., 0.025—0.04mm., 0.04—0.33mm., and says:

"Hence, if we presume in the preceding table that the average diameter is the mean of the extreme diameters 0—0.01, 0.01—0.025, 0.025—0.04, 0.04—0.33, i. e., 0.005mm., 0.0175mm., 0.0325mm., and 0.185 mm., the surfaces of equal masses of particles having these average diameters will be in the inverse ratio of these numbers i. e.,

$$\frac{1}{50} : \frac{1}{175} : \frac{1}{325} : \frac{1}{1850} \text{ or } 3367 : 962 : 518 : 91$$

Then multiply the percentage contents as follows:

0 —0.01mm×3367
0.01 —0.025mm× 962
0.025—0.04mm× 518
0.04 —0.33mm× 91

The total surface area will be the sum of these products."

Prof. Binns has given some interesting points in Vol. V., A. C. S. He makes mixes of kaolin and ball clay constant, with flint and spar normal, and ground in varying proportions. The evidence found is in short that the grinding of flint has a very marked effect, but that the grinding of spar has less. The action of the spar becomes much more powerful by grinding, and dissolves the clay substances already in combination much more readily than the flint, which being free silica remains in suspension. That the blends of spar and clay alone have the appearance of a fritt or slag.

"They seem to be not translucent but transparent, and to this fact is due their dark color. A new light is thus cast on the problem of color and translucency. Spar appears to render the clay mass transparent and dark because the rays of light penetrate and are not reflected. So when in the fused mass of spar there are present a large number of flint fragments, the reflection from these imparts whiteness and through the space between, the light rays can pass. Add to this the fact that most of the flint grains are in themselves translucent, and there is an explanation of the combined whiteness and translucency in the presence of flint which does not occur in its absence. Obviously then the fine grained flint will have a stronger influence for there are just so many more points for the reflection of the light rays. The grinding of spar has the effect of increasing its power at a given temperature."

Another article of considerable importance at this time is one by Arthur Heath, read at Victoria Institute, Tunstall, December 13, 1902. "The effect of varying fineness of particles of non-plastic materials in pottery bodies," is the subject. To obtain samples of the various sizes of flint and spar he uses sieves from 60's to 160's for those 0.239 to 0.1mm in diameter, and a Schoene apparatus for sizes from 0.08 to 0. The method of determining sizes was by actual measurement from micro-photographs of the particles magnified sixty times—the average of several being used. Using a standard earthenware body mix, two series of trials were made, one with flint and one with stone. The results, showing porosity and contraction, he expressed graphically on diagrams, and comes to the following conclusions:

1. "The flint of an earthenware body causes the contraction to vary inversely as the diameter of its grains.

2. Porosity varies directly with the diameter to 0.05mm.; below that it varies inversely as the diameter.

3. The effect on the glaze is that the tendency to craze increases with the size of the particles.

4. The stone in an earthenware body causes the contraction to vary inversely as the diameter of its grains.

5. Porosity varies directly as the size of the grains.

6. The effect on the glaze does not tend to crazing, but the eggshelly effect diminishes with the size of the grain; but when stone is less than 0.029mm. diameter it causes a blistering of the body when glazed."

In speaking of the surface area as compared with the diameter of grains, Mr. Heath assumes the grains to be cubes, hence for a given mass of material the surface area varies inversely as the diameters or edges of its particles or cubes.

The method used by the writer in the elutriation of flint and spar differ slightly from that used by Seger in that only particles which pass 120's lawn are considered, he having used a Schoene apparatus and a pressure great enough to separate particles 0.33mm. The largest particles which pass 120's lawn according to two measurements are 0.12mm wide, and length varying. These measurements were made first from the particles themselves as they appear under the cover glass, on a slide under the microscope, it being supposed the particles are flat, showing their two greatest dimensions, and second from a measurement of the meshes of the lawn used (120's), the greatest dimension of the opening corresponding exactly with the width of the largest grains which passed through.

The apparatus at hand is patterned after Schultz's, which consists essentially of three cylinders with cone-shaped bottoms placed at different heights, so that the overflow from the first flows through the thistle tube to the bottom of the second, and so from the second to the third. This works so nicely that the white cloud of flint or spar when it reaches the side of the cylinder rises with a perfectly flat surface on top. The water supply is constant, coming from a tank with an overflow and fed from faucet. The height of the tank depends on the opening in the end of the delivery tube, and is adjusted by trial. The cylinders have different diameters to produce a separation of the particles according to the sizes outlined by Seger, namely in the first or smallest can:—particles 0.12mm to 0.04mm in width, (0.33-mm to 0.04mm., Seger) in the second can, those 0.04mm to 0.025 mm in width, the measurement of the particles in the third can

being 0.025mm. to 0.01mm., and the final overflow consisting of particles from 0.01mm to 0.

The flint and spar used in these experiments are American flint and body spar from the Eureka Flint and Spar Co. The first difficulty that presented itself was the proper breaking up of the particles. Taking the flint and spar normal, or as it comes from the miller where it has been ground dry in ball mills or cylinders, a good boiling with care will loosen nearly all of the particles, and when put through the elutriation apparatus the particles are found in cans according to their proper size, the first can containing only particles from 0.12 to 0.04mm, the second can 0.04 to 0.025mm, the third can 0.025 to 0.01mm. But when the materials are reground wet, in a porcelain jar for 20 min., 40 min., 1 hr., 2 hrs., 4 hrs., and then dried, the finer portion is quite apt to set, and so boiling would not suffice. A sample ground for one hour was boiled and elutriated, but was not satisfactory, for in the first can particularly were found aggregations of these small particles acting as a large unit. Even passing the material through 120's lawn would not break up these clots, so finally another method was resorted to. A bottle about six inches long was placed in a frame of a ball mill so that the contents of the bottle would fall from one end to the other as the frame revolved. This helped to a considerable extent. The use of distilled water throughout the experiment and a shaking device for breaking up the particles would probably have given better results. By trial 20g. dry seemed to be a fair charge for the size of the apparatus. The advantages of this apparatus are its ease of manufacture putting it within the reach of all, it requires no attention while doing its work—a small supply of water from the tap accomplishing all.

The following table shows the result of a series of experiments, and the figures given are the product of the original figures by five since only twenty grams were used in the experiment.

TABLE I. FLINT.

Diameters in millimeters	Normal	20 min.	40 min	1 hr.	2 hr.	4 hr.	1 hr. dry.
0.12 —0.04	1.70	1.50	.....	.....	.....	.....	0.15
0.04 —0.025	15.85	15.80	11.15	3.55	2.65	3.50	12.10
0.025—0.01	25.25	25.40	28.25	26.25	23.80	11.60	25.00
0.01 —0.	57.20	57.30	60.70	70.20	73.55	84.90	37.25

TABLE II. SPAR.

Diameters in millimeters	Normal	20 min.	40 min.	1 hr.	2 hr.	4 hr.	1 hr. dry.
0.12 —0.04	8.85	.....	.....	.....	.....	.....	2.55
0.04 —0.025	15.95	12.25	6.15	8.80	5.50	4.00	10.05
0.025—0.01	22.35	23.70	18.50	28.45	29.50	13.00	23.40
0.01 —0.0	52.85	64.05	65.35	62.75	65.00	83.00	36.00

These figures are plain as far as the proportional amount of each size is concerned, but they do not tell us concerning the surface of the elutriated portions, and this point is of greatest importance. Mr. Jackson has so clearly shown a method of determining a surface factor that it seems unnecessary to find another factor, or even another method of finding the same factor. His method is based on the assumption that the particles are round or nearly so, and Mr. Heath mentioned how the same relation between surface area and diameter is true when the particle is considered a cube, and now it seems reasonable if the mean dimensions or width be taken, the same law should hold approximately true or be accurate enough for practical purposes. Accepting his method of finding the desired factor, and applying it to the sizes of the elutriated material as given in these experiments, the following results are obtained. The means of the following extremes 0.12—0.04mm., 0.04—0.025mm., 0.025-0.01mm., 0.01—0, are 0.08mm., 0.0325mm., 0.0175mm., 0.005mm. respectively, and their surfaces vary as $\frac{1}{800} : \frac{1}{325} : \frac{1}{175} : \frac{1}{50}$, or as 182 : 448 : 832 : 2912. From these numbers and the preceding table the following surface areas and factors are obtained:

TABLE III. FLINT.

Diameter in millimeters	Normal	20 min.	40 min.
0.12 —0.04mm.	309.40	243.00	.....
0.04 —0.025mm.	7120.80	7078.40	4950.40
0.025—0.01mm.	21007.00	21132.80	23504.00
0.01 —0.0mm.	166566.40	166857.60	176758.40
Totals.....	195003.60	195311.80	215212.80

Diameter in millimeters	1 hr.	2 hr.	4 hr.	1 hr. dry.
0.12 —0.04mm.	.....	.....	.....	27.30
0.04 —0.025mm.	1690.40	1187.20	1568.00	5420.80
0.025—0.01mm.	21840.00	19801.60	9651.20	20800.00
0.01 —0.0mm.	204422.40	214177.60	247228.80	182736.25
Totals.....	227422.80	235166.40	258448.00	208984.35

TABLE IV.

Omitting the last two figures, we have

No time	1950
20 minutes	1953
40 minutes	2052
1 hour	2279
2 hours	2351
4 hours	2584
1 hour dry	2089

TABLE V. SPAR.

	Normal	20 min.	40 min
0.12 —0.04mm.	1610.70	.....	.....
0.04 —0.025mm.	7145.60	5488.00	2755.20
0.025—0.01mm.	18595.20	19718.40	15392.00
0.01 —0.0mm.	153899.20	186513.60	190299.20
Totals.....	181240.70	211720.00	208446.40

	1 hr.	2 hr.	4 hr.	I hr. dry.
0.12 —0.04mm.	3942.40	.....	.....	464.10
0.04 —0.025mm.	3942.40	2464.00	1792.00	4502.40
0.025—0.01mm.	23690.40	24544.00	10816.00	19468.80
0.01 —0.0mm.	182728.00	189280.00	241696.00	186368.00
Totals.....	210369.80	216288.00	254304.00	210803.30

TABLE VI.

Omitting the last two figures, we have

No time	1812
20 minutes	2117
40 minutes	2084
1 hour	2103
2 hours	2162
4 hours	2543
1 hour dry	2108

The first comparison is made from Tables IV and VI where it is noticed that the flint as it comes from the miller has a greater surface area than the spar, the flint ground wet four hours has a greater surface area than the four hour ground spar, and the ratio between the amount of finest elutriated portion (0.01—0) and the surface factor in flint and spar is nearly constant or equal both in the normal and the four hours ground, showing that the amount of fine material is an indication of the surface factor, or if a lawn were at hand having the greatest dimension of its mesh 0.01mm., the amount of any material passing 120's lawn and remaining on the fine one, would determine the fineness or surface area.

TABLE VII.

Times.	Proportions.	Means.	Extremes.
Normal	57.2 : 52.85 :: 1950 : 1812	1030	1040
4 hrs.	84.6 : 83. :: 2584 : 2543	2145	2169

In comparison of the grinds of one hour wet and one hour dry, the spar shows no difference in surface factor, or practically none while the flint has a surface factor of 2279 wet and 2089 dry, which would favor wet grinding, for in round numbers the wet grinding accomplishes the same result in forty minutes that is accomplished by the dry process in one hour, or a saving of one third of the time. If upon further investigation these figures should prove correct, it would be a strong point in favor of wet grinding.

In an endeavor to see the effect of different degrees of fineness of flint and spar in a pottery body, at a heat equal to or above the melting point of spar, a few trials were made and fired at cone ten, and the following were selected as a basis for a series of experiments: Harris kaolin 30, Florida clay 25, spar 25, flint 20. This body seemed suited for the purpose on account of quite a percentage of absorption, which would allow for vitrification if the action of the flint or spar were increased in any instance by fine grinding.

The following table shows the flint and spar normal, in different grinds from twenty minutes to four hours, and elutriated:

TABLE VIII.

Ingredients.	Sample Numbers.									
	1.	2.	3	4	5.	6.	7.	8	9	10.
Harris Kaolin	30	30	30	30	30	30	30	30	30	30
Florida Clay	25	25	25	25	25	25	25	25	25	25
Normal Spar	25	..	..	..	25	25	25	..	..	..
Normal Flint	20	20	20	20	..	..	..	..	..	..
1 hr. Flint	..	..	..	..	20	..	..	20	..	..
2 hr. Flint	..	..	..	..	..	20	..	..	20	..
4 hr. Flint	..	..	..	..	..	..	20	..	..	20
1 hr. Spar	..	25	..	..	..	..	..	25	..	..
2 hr. Spar	..	..	25	..	..	..	..	..	25	..
4 hr. Spar	..	..	..	25	..	..	..	..	..	25

TABLE IX.

Ingredients.	Sample Numbers.				
	11.	12	13.	14.	15.
Harris Kaolin	30	30	30	30	30
Florida Clay	25	25	25	25	25
.04 —.025mm. Spar	25	..	..	..	..
.025—.01 mm. Spar	..	25	..	..	..
.01 —.0 mm. Spar	..	..	25	25	..
.04 —.025mm. Flint	20	..	..	..	..
.025—.01 mm. Flint	..	20	..	..	..
.01 —.0 mm. Flint	..	..	20	..	20
Normal Spar	..	..	..	..	25
Normal Flint	..	..	..	20	..

TABLE X.

Ingredients.	Sample Numbers.					
	16.	17.	18.	19.	20	21.
Harris Kaolin	30	30	30	30	30	30
Florida Clay	25	25	25	25	25	25
Normal Spar	25	25	..	..	..	..
Normal Flint	..	..	20	20	..	..
20 min. Spar	..	..	25	..	25	..
40 min. Spar	..	..	..	25	..	25
20 min. Flint	20	..	..	..	20	..
40 min. Flint	..	20	..	..	..	20

The first fifteen trials were already made when it was thought necessary to have grinds of less than one hour. This will explain the numbers of Table X.

TABLE XI. ABSORPTION.

Sample number.	Percent.	Sample number.	Percent.	Sample number.	Percent.
1	2.75	8	0.91	15	0.07
2	2.03	9	1.37	16	2.59
3	1.40	10	0.05	17	1.90
4	0.33	11	6.92	18	1.20
5	2.32	12	5.03	19	2.39
6	2.41	13	0.10	20	1.67
7	1.12	14	0.88	21	1.18

These trials were made small by necessity, since some of them contained the elutriated material of which only a limited

supply was obtained. They were mixed to a slip in a small mortar, dried on a plaster bat until workable, then pressed into molds to make slabs 1½ in. x 3 in. x ⅛ in. These slabs were set on edge and partly embedded in flint, that is, enough to hold them in upright positions, and all in one saggar so there could be no difference in temperature, a check of two cones (10), one placed in each end of the saggar was used, and both fusing and bending exactly alike.

No. 1, containing spar and flint normal showed a rough and dry fracture with a somewhat variable structure, that is to say, the spar and the flint are in part coarse grains. When these larger grains melt, from a lack of fine materials to combine with the spar, they remain as such without holding flint or kaolin in suspension or solution or combining with them. Nos. 18, 19, 2, 3, 4, represent flint normal with spar ground twenty minutes to four hours, the fracture remains about the same concerning roughness, but the particles seem to be cemented together more intimately, and from the absorption table this would be true.

Nos. 16, 17, 5, 6, 7 have a constant of normal spar with the grinds of flint varying from twenty minutes to four hours. These results are inferior to previous ones because Nos. 5, 6, 7, were found to be improperly mixed and contained flakes of flint particles showing white dry spots, and if these are mostly the finest of the flint the results are far from accurate. Comparing Nos. 17 and 19, which represent equal grinds of flint and spar respectively, there appears a difference in results in favor of flint, but the other numbers are so erratic nothing definite can be proved.

Nos. 20, 21, 8, 9, 10, show a gradual increase towards vitrification, and upon consulting Table XI it is found that the absorption runs from 1.67% to 0.05%, or probably none. In trials 11, 12, and 13, elutriated spar and flint were used. No. 11 was a very porous body with 6.92% absorption. No 12 had a somewhat finer texture and fracture, but showed 5.03% absorption. No. 13 was a fine-grained, slightly blueish body, showing little or no absorption. No. 14 showed as compared with No. 13 a dryer fracture, and color whiter (a little toward yellow) with 0.88% absorption. No. 15 showed a whiter body than either 13 or 14,

vitreousness the same as 13 with no absorption. By comparing Nos. 18, 19, 2, 3, 4, with 16, 17, 5, 6, 7, we should be able to see the relative merits of spar versus flint grinding, but the results are not complete, however, the trials which seem to be made correctly would tend to confirm the idea that the grinding of flint exerts a greater influence on the body than the grinding of spar.

Trials Nos. 20, 21, 8, 9, 10, with spar and flint both ground twenty minutes to four hours, serve to show the relative action of different grinds of materials and to make a comparison with their corresponding surface factors, that is, No. 1 contained normal flint and normal spar, with surface factors 1950 and 1812 respectively, while No. 10 contained four hour flint and four hour spar, with surface factors 2584 and 2543 respectively, and the increase in grinding reduces the absorption from 2.75% to nothing.

Nos. 11, 12, 13, show the effect of different elutriated portions of flint and spar, 0.04—0.025mm., 0.025—0.01mm., 0.01—0, and show absorptions of 6.92%, 5.03%, and no % with corresponding surface factors 448, 832, and 2912, which adds further testimony to fine grinding, for it is dependent on the finest particles which are produced only by continued grinding. The fine particles seem to have a greater effect than their surface factors would indicate, and the following explanation is offered: The weight of particles under 0.005mm. probably exceeds that of diameter 0.005—0.01mm., and would have a correspondingly increased action while in figuring the surface factors only the average dimension is used, regardless of quantity. It would seem likely that the average effect of grains between 0.01mm. and 0 would vary with different grinds.

No. 14 has normal flint and 0.01mm.—0 spar and No. 15 vice versa, and from them we see the relative merits of grinding flint and spar separately, for No. 15 excels in vitreousness and whiteness. No. 15 is superior to No. 13 in whiteness and equal in vitreousness, the conclusion of necessity being that the fine grinding of flint alone is preferable.

All of the twenty-one trials were dipped in a glaze of Seger cone four composition, and fired to cone nine to ten. They were just a little under fired, and had a slightly orange skin surface, but without crazing or shivering.

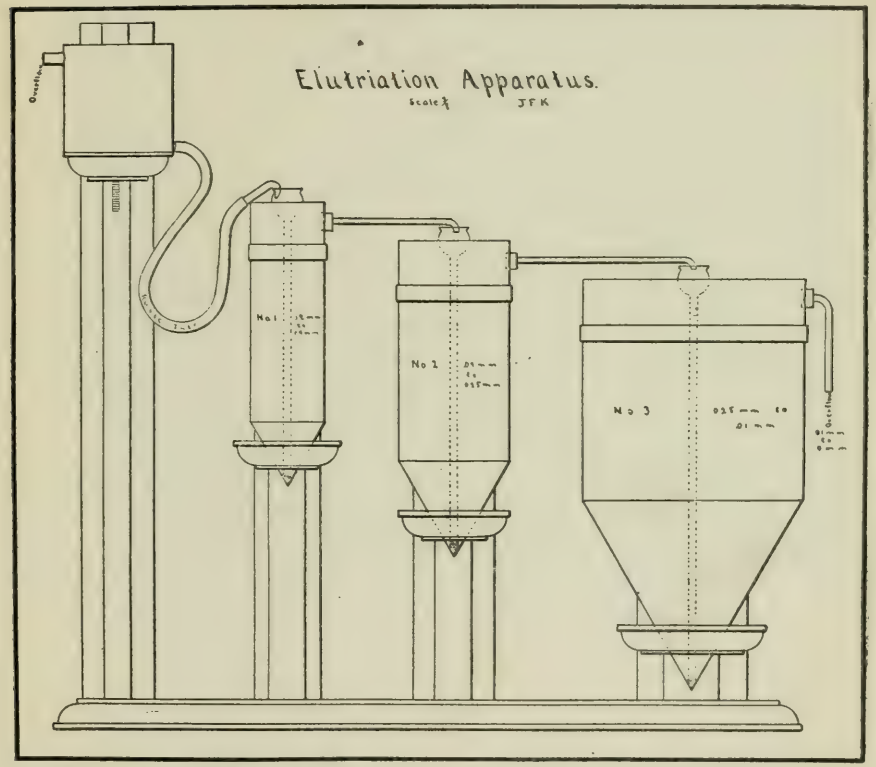
While these experiments have been carried on only in the laboratory, and not in a practical way, they show:

That there is much yet to be done in this line of work.

That it is possible to have a more accurate test for fineness than the mere passing of 160's lawn.

That it is better to grind flint than spar.

That the surface factor of flint should be about 2500, and that of spar from 2500 to 1800.



ELUTRIATION APPARATUS USED BY KREHBIEL IN HIS MECHANICAL SEPARATIONS.

NOTES ON THE PRODUCTION OF CRYSTALLINE GLAZES.

BY

RAY T. STULL, E. M. (in Cer.), Elkland, Pa.

Perhaps no other portion of the ceramic field is more inviting for experimental work than the field of crystalline glazes. Certainly no other branch of glaze making is capable of producing so many beautiful and startling results. Up to the present time, the work which has been done in Europe and America in crystalline glazes has opened up a new field, not yet popular with the public, but of the most intense interest to the scientific student.

Crystalline glazes may be divided into two classes. First, those in which the crystals are produced by the so-called supersaturation method, and second, glazes in which the entire mass has a crystalline structure.

The first class comprises the Aventurine glazes, as the "Goldstone" or "Tiger-eye." Such a glaze is produced by a mixture in which there is an excess of one or more metallic oxides, or by applying these oxides to the body or bisque before dipping in the glaze. Upon firing, the glaze proper or glassy matrix liquefies. This liquid is capable of dissolving more or less of the metallic oxide or oxides present. In cooling, the capacity of the glassy liquid to hold its dissolved material in solution is lessened, hence the excess is deposited as crystals within a glassy matrix, or produces an opaque result due to incipient crystallization.

The second class comprises the true matt glazes, or those in which the whole mass is crystalline, and those glazes in which the crystals arrange themselves in groups and fern shapes not unlike the appearance of galvanized iron, frost crystals on the window, or crystals produced by a solution of epsom salts on a plate glass.

The writer's first experiments in crystalline glazes were conducted for the purpose of determining, if possible, what total oxygen ratios were best suited to the production of crystalline effects. It was found that crystalline glazes could be produced with almost any total oxygen ratio, depending primarily upon the composition of RO, and secondarily upon the acid elements.

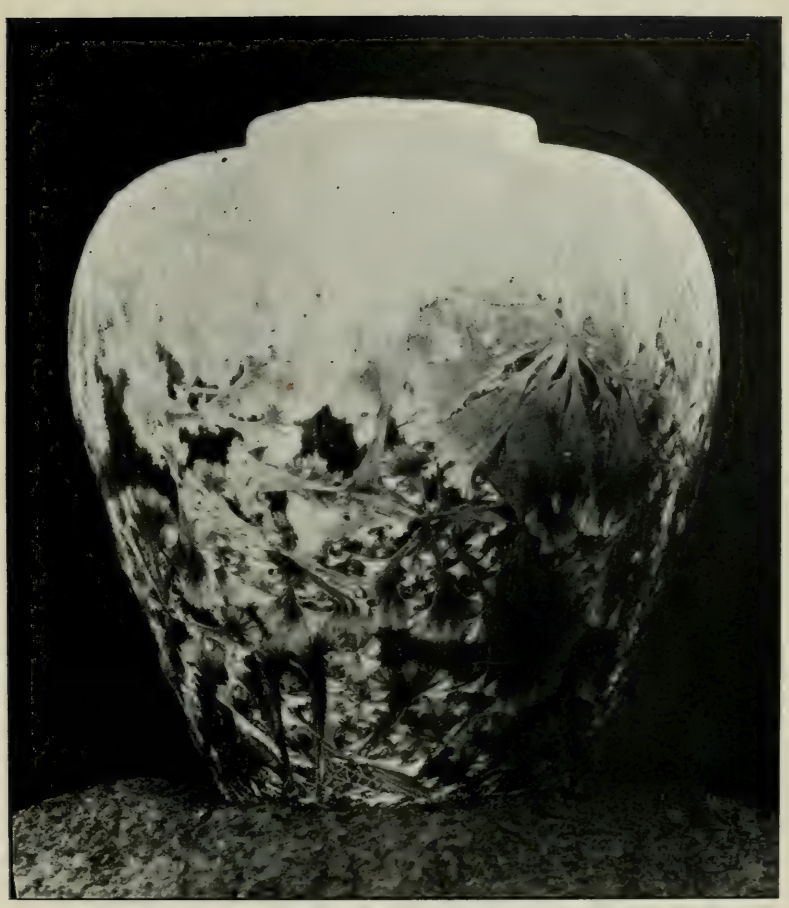


FIG. 1 —CRYSTALLINE TITANO-SILICATE GLAZE.

These glazes were mostly of the matt type, and not the kind that were sought.

The total oxygen ratio idea was abandoned, and the next line of experiments was carried on for the purpose of determining what ceramic materials gave to glazes the best tendencies to crystallize. The results of these experiments seemed to permit the following general deductions:

I. The strongest crystalline tendencies are given to glazes by those chemical elements of low atomic weight whose oxides go to make up the RO, such as sodium, potassium, magnesium, calcium, manganese, iron, zinc, etc.

II. Those metals of high atomic weight, such as barium, lead, etc., seem to impart a glassy nature to silicates when used in sufficient quantities, which is unfavorable to crystallization.

III. Those chemical elements of higher atomic weight whose oxides make the acid portion of a glaze such as silicon, titanium, phosphorus, etc., produce the best crystallizing agents, while those of lower atomic weight, as for example, boron, having an atomic weight of 11, impart a fluidity and brilliancy to a glaze which is detrimental to crystallization.

IV. The introduction of an R_2O_3 materially assists crystallization in some cases, while in others it is detrimental to it.

After determining what materials were the best crystallizers, the next problem was "How should they be combined in order to produce the best crystalline results?" Since beautiful crystaline silicates are found in nature, the subject of mineralogy was consulted. The idea which first suggested itself was, "Why not make artificial mixtures representing silicate minerals and use them for glazes?" This was tried with a small degree of success.

In attempting to make crystaliine glazes whose final formulae correspond to those of natural silicates, one finds himself restricted to those silicates which have neither water of combination or crystallization. This confines one mostly to the following twelve mineral groups:

1 Feldspar	5 Nephelite	9 Chrysolite
2 Leucite	6 Sodalite	10 Phenacite
3 Pyroxene	7 Helvite	11 Zircon
4 Amphibole	8 Garnet	12 Danubite

A great many of the minerals under the above groups are fusible at ordinary ceramic heats, but the results obtained from ceramic mixtures corresponding to such minerals were mostly disappointing. Perhaps this was largely due to the fact that the conditions under which these minerals crystallized in nature could not be duplicated in the kiln.

The best results of the writer were produced in a manner similar to the following:

Mineralogically the silicates are divided into the following groups:

I. Disilicates, RO, 2 SiO_2
II. Polysilicates, 2 RO, 3 SiO_2.
III. Metasilicates, RO, SiO_2.
IV. Orthosilicates, 2 RO, SiO_2.
V. Subsilicates, whose true composition is doubtful.

Let us now select any one of these groups in which to experiment, as for example the metasilicate group, and from this group select a mineral, as for instance, wollastonite; (CaO, SiO_2). It would not be practical to make up a glaze whose final formula would theoretically correspond to this, because it would require too high a temperature to develop it under ordinary working conditions; but we may soften it down by replacement, as for example, by substituting Na_2O for part CaO and still maintain it a metasilicate.

Theoretically this replacement should be made in a simple ratio of Na_2O to CaO, as for instance Na_2O : CaO : : 1 : 1, or 1 : 2, or 1 : 3, or 2 : 3, etc.

By making up a glaze according to each of these ratios we would have:

Ceramic Formula.	Mineralogical Formula.
0.5 Na_2O, 0.5 CaO } SiO_2	Na_2O, CaO, 2 SiO_2
0.33 Na_2O, 0.66 CaO } SiO_2	Na_2O, 2 CaO, 3 SiO_2
0.25 Na_2O, 0.75 CaO } SiO_2	Na_2O, 3 CaO, 4 SiO_2
0.2 Na_2O, 0.8 CaO } SiO_2	Na_2O, 4 CaO, 5 SiO_2

These glazes would all come under the head of metasilicates.

Na_2O may be replaced wholly or in part by K_2O, and CaO may be replaced wholly or in part by MgO, FeO, MnO, CoO,

FIG. 2—CRYSTALLINE TITANO-SILICATE GLAZE.

ZnO, CuO, etc., or combinations of them according to the above molecular ratio theory; but it is better to keep the RO down to one, two or three metallic oxides for the following reason, viz: Increasing the number of metallic oxides in the RO tends to increase glassiness as well as fusibility.

The acidity of a glaze may be raised, bringing it from one silicate group into the next one higher, as for example, from a metasilicate to a polysilicate, or from a polysilicate to a disilicate, and similar laws may be followed for substitutions in the acidity as are followed for substitutions in the RO.

In like manner any other mineral from one of the above named groups may be selected as the starting point for experiments.

Since the use of titanium oxide in glazes showed that they had a strong tendency to crystallize, a titano-silicate mineral, known as astrophyllite, was selected for the starting point. The general formula of this mineral is $R'_4R''_4$ Ti (SiO_4) , or $(R_2O$, 4 RO, TiO_2, $4SiO_2)$, in which R′=H, Na, K and R″=Fe, Mn chiefly, including also Fe_2O_3. It occurs in elongated crystals, also in thin strips or blades; sometimes in stellate groups.*

In making up experimental mixtures, based on the astrophyllite formula, other members of the RO family besides FeO and MnO were tried. Applied as glazes, they come from the kiln with a dry or dull surface, with occasional crystals in small stellate groups. After working for some time in this direction without success, it was decided to try the effect of increased acidity, which was raised from $R'_4R''_4$5 acid to $R'_4R''_4$ 12 acid, which may be written, R_2O,2(RO), 6 acid. This formula is very suggestive of the feldspar formula, except that 2(RO) takes the place of Al_2O_3, and the acid being made up of part TiO_2 instead of all SiO_2.

Before the acidity was raised, it was discovered that the addition of a small amount of Al_2O_3 increased the size of the crystal groups. It seemed possible that the Al_2O_3 took the place of Fe_2O_3, which sometimes occurs in astrophyllite. The great objection to Al_2O_3 is that it tends to increase the dryness or dullness of the surface. The best results, however, were obtained from the formula R_2O, R_2O_2, 6 acid, in which Al_2O_3 was left out.

* A Text Book of Mineralogy, Dana, pp 487, 1900 Edition.

Under favorable conditions, a glaze having a strong tendency to crystallize will do so on either a raw or biscuited body, but the best results are obtained by applying the glaze over a hard vitrified body which has been fired two or three cones higher than the temperature at which the glaze matures.

The glaze should be of such a nature that when fused it has a medium degree of fluidity or mobility, and should be applied quite thickly, especially at the top of the piece to be glazed and allowed to flow down the sides.

The heat treatment depends upon the composition, physical nature and crystalline tendency of the glaze. When the firing temperature has not been carried high enough, or has been stopped too suddenly, the glaze will frequently lie in too thick a layer upon the piece, crystallizing in a matt surface.

The firing should be stopped at the right stage, so that enough glaze remains upon the piece in order to form the crystals. If the glaze has a strong tendency to crystallize, the cooling period need not be very long. Glazes with a weak or slow tendency to crystallize should be given longer time in which to cool.

When the glaze has been over fired, or the temperature for maturing held too long, the glaze will frequently "drain off," not leaving a layer thick enough to form crystals. It is probable that the thin layer remaining unites with, or dissolves a portion of the body surface, forming a new glaze of unknown formula.

Proceeding as indicated above, the writer succeeded in producing glazes which gave very large and fine crystalline effects. In fact, the vigor of the crystallization is too great rather than too small, as where the conditions are correct, the glaze crystallizes so coarsely as to mar the smoothness of the glaze. One most surprising and noteworthy phenomenon in this connection was observed: where a crystalline needle happened to be growing vertically upwards, it would sometimes fail to turn the comparatively sharp angle at the shoulder of the vase where the constriction for the neck begun, but would be projected out into the atmosphere in a straight line with its previous direction. These crystals thus formed occasionally a fringe of long sharp needles projecting an inch or so from the point where they left the glaze matrix. Illustrations of crystalls growing from a fluid out into

FIG. 3—CRYSTALLINE TITANO-SILICATE GLAZE.

a gas are not unknown, but when the fluid is a red hot silicate, the instance is certainly unusual, if not new.

The character and size of the crystalls obtained in the preceding experiments may be seen from the photographs reproduced in figures 1, 2, 3 and 4. Their striking similarity to the frostwork on a window pane will be noticed. Also their relationship to the crystalls formed on glazes by epsom salts, (Fig. 5) or on iron by molten zinc (Fig. 6). These substances, also when they crystallize in a thick layer, produce a dull frosty or matt surface.

Whatever the actual composition of the crystalline mineral may be which forms so persistently in this glaze, it still seems to have the power to absorb coloring matter, or to use coloring oxides as a part of its make-up. The base of them all is the same pearly white frit. All the common colors are easily produced by adding from .03 to .05 of the coloring RO to the formula instead of substituting it into the formula; for example, in the case of the blue crystals, the formula theoretically would be, $R_2O, 2(RO)6$ acid$+0.03$ CoO. With the exceptions of cobalt and uranium, (and in some cases copper, which is quite volatile), any increase of coloring oxide above .05 seems to act as an impurity, which interferes with crystallization, but in most cases .03 of the coloring oxide may be added without materially retarding crystallization. A little Cr_2O_3 will produce crystals of a peculiar chrome-green color, but when increased to any extent it destroys the crystalline grouping, producing long needle-like crystals, giving a pleasing matt effect.

The satiny surface of the most beautiful and rare matt glazes is due to the interlacing of long needle-like crystals, whose major axes are approximately parallel to the glaze surface. The formula of such a glaze generally classes it under the head of a polysilicate or metasilicate.

The ordinary matt glaze generally has a formula which is more complex, or one which would place it somewhere between a disilicate and a polysilicate, a polysilicate and a metasilicate or a metasilicate and an orthosilicate. Such a glaze when examined carefully under the microscope will often reveal two or more crystalline forms belonging to two or more crystalline groups or systems.

Although there is no evidence at hand as proof, the follow-

ing explanation is suggested: The formula of a matt glaze often places it somewhere between two silicate groups. This glaze when fused is a complex silicate mixture. Upon cooling, these complex silicates break up, crystallizing out into the simpler forms, each form having a different composition. The same thing is met in nature in the granitic rocks, which are mixtures of crystaline minerals composed principally of hornblend, mica, feldspar and quartz.

The composition for a good matt glaze should be such that the glaze in fusing has a slight flow, and yet be viscous enough to retain a sufficiently thick layer so as to crystallize, giving a matt surface. The viscosity of most matt glazes is due to the fact that they are either highly basic, highly aluminous, or contain a high content of tin oxide.

A great many matt glazes on the market are highly basic. This is proven by the acid test. Dip a matt glaze in hydrochloric acid or place it over a beaker of strong hydrochloric acid so that the fumes can strike it. If it is readily attacked by the acid it is evidence that the glaze is of the highly basic variety. Most matts which stand the acid test are those maturing at or above cone 3, but not all matts maturing at these temperatures will withstand the test.

The majority of matt glazes of the basic variety when over fired have a tendency to become brilliant. This may be due to the three following causes: First, volatilization of part of the base, which is practically the same as increasing the acidity. Second, the body being highly silicious and the glaze highly basic, the base would naturally unite with more or less silica, hence increasing the acidity. Third, there is an interference to free crystallization due to thinness of the glaze layer and change in its composition.

In experimenting with crystalline glazes, one should not arrive at a conclusion or be contented with one single burn, but trials should be placed in different parts of the kiln and several burns should be made; for the reason that unaccountable factors often enter to change the final results.

This is especially true in the kiln. Three burns of the same glaze mix were made before the result represented by Fig. 1 was obtained. Often several vases with glaze applied from the same

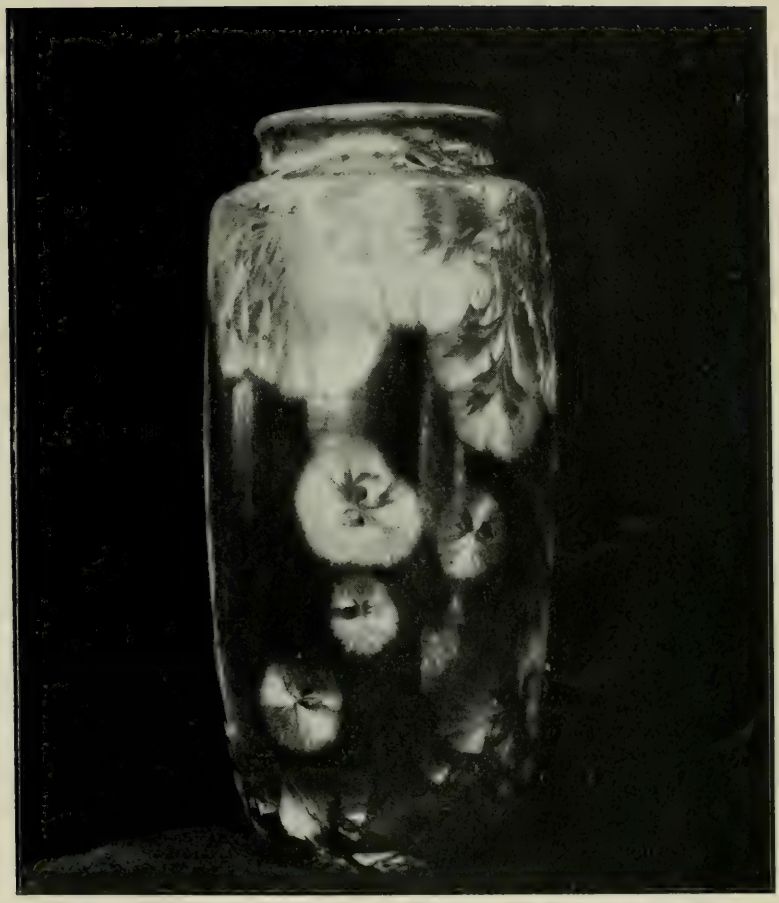


FIG. 4—STELLATE CRYSTALS, 1″ TO 1½″ IN DIAMETER.

mix are burned together in the same saggar. On removal from the kiln there may be one vase completely covered with an extremely beautiful crystalline formation, while all the other vases surrounding it may have their crystals arranged in different formations, or have very few crystals or none at all. Why this wide difference in final results should occur is hard to determine.

Apparently they all receive the same treatment throughout. If there is any difference in temperature in close proximity within a saggar, this difference is so small that it cannot be detected by the pyrometer or by the use of cones.

Discussion.*

Mr. S. Geijsbeek: Mr. Stull mentions willemite, the natural zinc silicate, Zn_2SiO_4. I has been stated several times in recent literature that this mineral is a good material for producing crystalline effects, but in making some experiments along this line, I have not found this mineral to be of any great value.

It appears to be better to make this mineral formation in the glaze, in order to enable the willemite to crystallize out of the recrystallize itself. As it is hard to carry zinc in the RO bases glaze, than to introduce the willemite as such, and have it merely of a glaze to a high amount, it is easier to reproduce the effect by super-saturation and using two glazes.

Starting with a glaze of the Bristol type, I progressively saturated the same with zinc oxide, until the last member of the series was

$$\left.\begin{matrix}0.075\ K_2O\\0.175\ CaO\\0.750\ ZnO\end{matrix}\right\}\ 0.125\ Al_2O_3,\quad 1.00\ SiO_2$$

This glaze showed some signs of crystallization on a nearly vitrified biscuit body. The glaze itself was poor, and changing the formula so at to produce a clearer glaze, the result was

$$\left.\begin{matrix}0.12\ K_2O\\0.28\ CaO\\0.60\ ZnO\end{matrix}\right\}\ 0.16\ Al_2O_3,\quad 1.04\ SiO_2$$

Sometimes this glaze would crystallize, but the clear glaze was more in evidence. It was plain that this glaze was just at

* Mr. Stull's paper was first given as an off-hand talk without preparation. Subsequently, he revised the stenographic notes, in the above form and added the illustrations. The discussion following was the one actually held on the extempore talk and does not wholly connect into the paper as now printed.—Editor.

the point at which it was saturated with zinc oxide, and that some additional zinc would always produce crystalline separation.

After some experimenting by raising the zinc in the RO bases, and more or less addition of SiO_2 in order to make the glaze mature at cone 8, it was found that this method was not very satisfactory for producing better results. I then tried the method of using two glazes, one on the other. Using the clear glaze formula mentioned above, I dipped the burned ware in a mixture of the composition, 2 ZnO, SiO_2. The results were no better. Using less zinc, the next experiment was a coat of ZnO, SiO_2. It gave a matt surface in which the crystalline effect was present, but not pronounced enough. The crystals were plentiful, but small in size. I raised the acidity in the coating to ZnO, 2 SiO_2, and produced some nice crystals about the same as on this little jar (indicating).

The shape of the crystals are needle-like star formations, and well defined. As there was no coloring matter in these experiments these crystals were pure zinc crystals. If I dipped the biscuit piece first in the glaze, and after the same was dry in the second zinc mixture, the effect was not as good as by burning the glaze first, and giving it a second fire with the zinc silicate coating.

The production of this crystalline effect is no doubt caused by the saturation of the glaze with zinc.

As I was working at that same time with colored glazes, such as Seger used on Seger porcelain, I coated these once burnt glazes with this same zinc silicate mixture, which gave the best crystalline effect.

The formula was

$$\left.\begin{matrix} 0.3\ KO \\ 0.7\ CaO \end{matrix}\right\} Al_2O_3,\ 4\ SiO_2$$

with either chromium, nickel or cobalt for color. I got some very pretty effects, and while I did not get as large crystals as Mr. Stull shows us here, they were larger than in the plain zinc glaze.

There was one strange effect which I got with nickel. The dark blue cobalt glaze turned out a light sky blue, but the nickel

Fig. 5 Epsom Salts, Crystallized on Glass.

Fig. 6—Metallic Zinc, Crystallized on Iron.

glaze which was brown in the first fire, became the prettiest Persian blue I ever saw. I am sorry I did not bring a sample with me to show you the color which it produced. I was astonished to know that from nickel, a blue color could be produced; it must be a nickel zinc silicate. In chromium, the original green disappears and the color turns brown, more like the ordinary nickel color.

Gentlemen, this about covers my experience with crystalline glazes.

Mr. A. V. Bleininger: I would like to ask Mr. Geijsbeek whether he has examined the nickel in regard to possible traces of cobalt? Last summer Dr. Pukall, Director of the Ceramic School at Bunzlau, said in regard to obtaining blues from nickel, that in every case he found traces of cobalt in the nickel. It is well known that the two metals are hard to separate.

Mr. Geijsbeek: That may be where the blue came from. I think I used as pure a nickel as we can obtain, but there may have been small traces of cobalt in it. I have found data to the effect, however, that Le Chatelier and Chapuy in Paris obtained the following list of colors with nickel in oxidizing fire, viz: violet, blue, green, yellow, red and brown. Dr. Zimmer in describing the crystal glazes of the Royal Copenhagen Porcelain, also mentions the fact that they produce a Persian blue with nickel and blue crystals of the same shade.

Prof. Binns: That is a most interesting point, one quite new to me. I have done some work along this line, using a soluble nitrate of nickel, dissolving it and charging the biscuit ware with the solution, then covering with a crystalline glaze. I found the body a light brown and the crystals blue. I know cobalt has a fashion of following crystals, similar pieces charged with a solution of cobalt nitrate will show dark blue crystals on a pale blue ground, which becomes almost colorless at times. However, what Mr. Bleininger said is true, and the suspicion is that the action of the crystallization has withdrawn the cobalt from the nickel and left the nickel to color the body. It is an interesting suggestion, and I hope it will be followed out.

Mr. W. D. Gates: I want to call Mr. Stull's attention to one point of which he omitted to speak; and which is a very interesting thing in this crystalline ware. It is the tendency of

of the crystals to absorb the coloring oxide from the enamel mixture in some instances, and in others to refuse to absorb it. It seems as if the crystals had a selective capacity for some colors and an intense dislike for others. I have no pieces here which show that, but it is very clearly seen on some of the pieces. The crystals sometimes are surrounded with a rim of undissolved particles of coloring oxide, which they seem to have expelled from the area of crystallization, while in other oxides the color was all taken up.

Prof. Edward Orton, Jr.: I would like to inquire of Mr. Stull whether the crystalline effects in the pieces he has shown here are produced by the application of two different glazes, the lower one to produce the glaze and the surface matt the crystals, or whether the glaze coat is all one thing?

Mr. Stull: It is all one thing. The glaze is applied on the biscuit. I have, in some cases, put it on a raw body. I have gotten the effect on fire brick and on red and buff clay. If the glaze composition is right, and the firing is right, the crystals will form on almost anything that will withstand the temperature for maturing the glaze.

Prof. Orton: Do I understand that these formulae you have put on the board are the actual formulae of glazes from which you have worked?

Mr. Stull: Yes; as nearly as I can give them from memory.

Prof. Orton: I had a different idea previously, and asked the question to reassure myself.

Mr. S. G. Burt: We are all interested in crystalline glazes, and I have been trying to settle my mind on the question of the absorption of cobalt color out of a glaze as a whole. I remember speaking two years ago to Mr. Bleininger on the subject, and his saying that it was perfectly possible that crystals of zinc silicate and cobalt silicate should mutually incorporate each other, if both are of the same crystalline form. Professor Binns has suggested the possibility of the color being merely drawn up, in the absorption sense. And I was thinking this afternoon of the interesting remarks by Mr. Cushman on colloid bodies, and their absorption of colors. Which of these methods really prevails? I don't feel satisfied that these are combined crystals from cobalt and zinc. If the two silicates crystallize together, it seems that

the resultant body should take on a new and different character.

Mr. Stull tells us that the piece with the large blue crystals is of the identical composition of the small piece in which the naked eye can detect no crystals, though the microscope shows millions there. It seems to prove what I read some time ago, that one crystal will go on eating up others growing larger all the time; so that, given the proper conditions, the size of the crystals seems almost unlimited. I should like to know whether Mr. Stull has been able to take the iron oxide, of which he speaks of as a good crystallizing agent, but of which the crystals generally are very small, and maintain such a condition as will cause them to grow to larger crystals?

Mr. Stull: The first crystals which I produced were from a formula similar to astrophyllite, which is composed of iron, potash, silica and titanic oxide, and is high in iron. Those crystals were dark iron red, but small.

Professor Chas. F. Binns: They belong to the same crystalline system?

Mr. Stull: Yes.

Professor Binns: Why can't they be built larger?

Mr. Stull: They might be, if carried further. By raising the acidity, we might get larger crystals. The crystals will dissolve 0.03 equivalents of manganese readily, as a coloring agent, but not any more. On the edge of the crystals, the excess oxide will not be crystalline, and will look darker than the crystal itself. The addition of a little iron with the manganese gives the crystals a deep, rich brown color. The crystal then seems to take all the manganese it can hold. It takes copper readily, and a peculiar thing is that many times on the outer edge of the green, the crystal will be red. What this red is, I do not know, unless it is a lower oxide of copper. I also had some large pure white crystals, fired in the same saggar with the copper green, which came out fringed around the outer edge with red—possibly due to the volatilization of the copper.

NOTE ON A BLACK SPECKLE FOR USE ON A RED FACE BRICK.

BY

LAWRENCE E. BARRINGER, E. M., (in Cer).

Research Laboratory, General Electric Co., Schenectady, N. Y.

For a number of years face brick have been made in a variety of colors and shades. The clays in general use as the basis of these colors are usually buff-burning fire clays which, by the introduction of ground pyrolusite, are converted into light and dark gray, gray speckled and buff speckled, according to the amount and degree of fineness of the manganese ore. With the same class of clays, brown and old gold and other shades are produced by "flash" firing.

With red-burning clays there has not been attempted much variety of shade beyond the pink or terra cotta colors produced by blending red and buff clays in certain proportions.

At the suggestion of Mr. L. G. Kilbourne, of the Columbus Brick and Terra Cotta Co., the writer undertook several years ago to produce a "red mottled" brick, i. e., a black speckle on a red body, corresponding to the buff mottled brick obtained by adding coarse pyrolusite to No. 2 fire clays. The raw pyrolusite could not be used in the red-burning clay, as in the buff, because at the temperature at which the red clay burned to a hard, dense body (cone No. 1) there was no fluxing effect on the pyrolusite, and it remained in the body only as hard black unfused grains, like powder grains, entirely different in appearance from the fused patches obtained at cone No. 8 when used in the buff clay.

Accordingly, it was necessary to use a manganese frit which would fuse into the clay at the temperature at which the red clay bricks were burned. The clay was a shale overlying the Lower Mercer fire clay, and when made into dry press bricks burned hard at cone No. 1 to a rich, dark red.

After a few trial frits, it was found that one of the composition

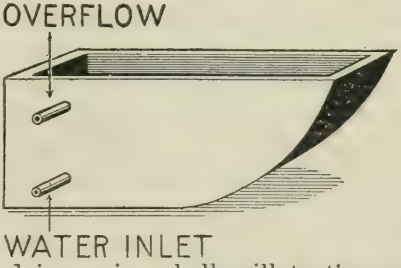
$$\left.\begin{matrix} .747\ MnO_2 \\ .253\ Na_2O \end{matrix}\right\} .509\ SiO_2$$

gave satisfactory results as to the melting point and color. The materials used were commercial ground pyrolusite, soda ash and flint. The pyrolusite used analysed

MnO_2	81.01
Fe_2O_3	5.73
Silicious Residue	13.26
	100.00

Most of the ores on the market contain both silica and iron, and in compounding the above frit it would be necessary to determine and allow for the silicious residue. The iron does not interfere seriously with either the color of the frit or its melting point.

The first frits were melted in flint-lined fire clay crucibles in a blacksmith's forge. Later a gas furnace was used and finally, when it became necessary to make up large quantities of the frit, a frit furnace was devised to work continuously and do away with the crucible. To this end, a furnace was constructed having an inclined, fire-brick floor sloping at an angle of about 30°. Above the upper end of this melting floor, in the roof of the furnace, was an opening through which to introduce the raw frit mixture, while below the lower end a receptacle was placed to receive and chill the molten frit. A stack was built at the upper end of the furnace, and natural gas burners arranged at the lower end. The sketch, Fig. No. 1, shows the general idea of the furnace, being a longitudinal section through the middle. With this furnace 100 pounds of frit could be very easily melted in eight hours. The receptacle to chill the frit may be made of galvanized iron and should be provided with inlet and outlet tubes to take off the hot water and feed in cold water in order to keep the temperature down. The front should be shaped as shown, so as to allow removal of the frit with a shovel or scoop without disturbing the receptacle.



The fused frit was ground in an iron ball mill to the required degree of fineness.

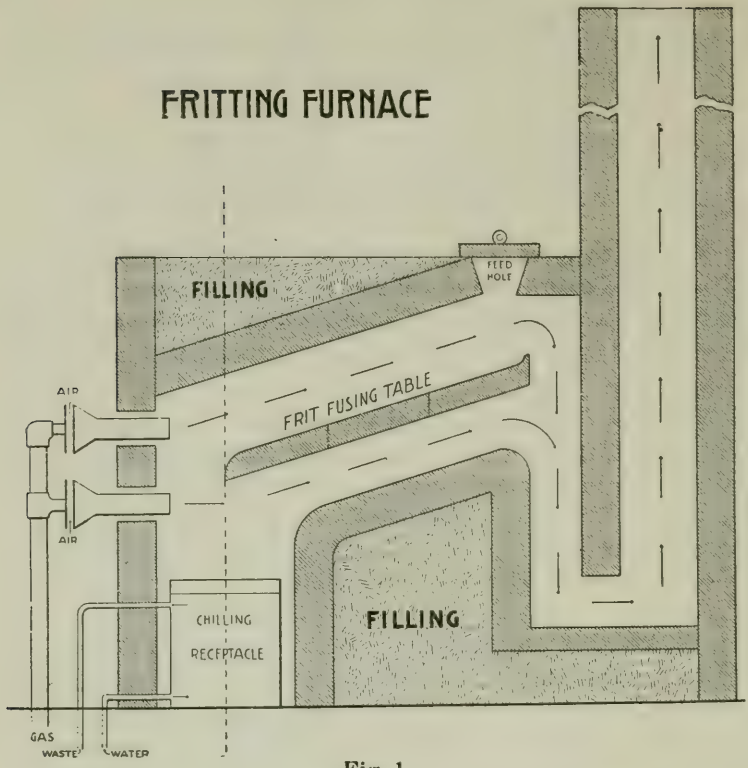


Fig. 1.

At first the attempt was made to secure the effect by mixing in with the red clay a certain per cent. of the ground frit, thus disseminating the grains all through the body. For this purpose the frit was used in grains from 30 to 60 mesh. Different percentages were tried, and half-size dry press bricks were made of the mixtures and burned to cone No. 1 in a small experimental kiln, the bricks being set on flat. The result was a beautiful glassy speckle all through the red body, showing about the same on the inside as on the outside of the body. The frit had fused, but in beads too small to be noticeable at a distance, and even with three per cent. of frit, the highest amount tried, were entirely devoid of any striking effect. On trying to increase the size of the spots it was found that 3 per cent. of frit, in grains from 24 to 40 mesh, gave fair results, but the large amount of

the contained frit in grains of this size fluxed the clay considerably, and resulted in cavities in the face of the brick which detracted seriously from its appearance. Facing the brick was tried and gave larger and more effective blotches, but did not remedy the trouble of cavities. Another great disadvantage of using the frit in this way was that of the expense of the process. It required much labor to get the frit in the size of grains desired, and a large part of it had to be remelted, having been ground too fine.

The scheme of grinding the frit to a fine powder, making this into a slip and spraying this on only the faces of the bricks was then thought of, and some of the frit was accordingly ground to 120 mesh, made into a thick slip and flecked onto a truck load of bricks with a brush. These were placed in the kiln as usual and were burned faced. The result was a red face mottled with glossy black spots, which gave the desired effect.

The work was now continued on a larger scale, and an atomizer worked with a foot bellows was tried as a means to spray the slip on the bricks, but this was found to be undesirable on account of the spots being of too uniform size. There was also considerable trouble with the atomizer connections clogging, as the frit settled very fast, choking up the tubing. By speckling with a brush by hand the size of the spots could be varied at will, and the method was also sufficiently rapid. An ordinary shaving brush was found satisfactory, and with this and a pan of slip the bricks would be speckled over the faces as they lay on the truck. This was done as each truck passed on its way to the kiln. and required about a minute. The mottled bricks were burned in the usual way in a continuous kiln. As the front of the chamber was approached in setting, this being the hottest part of the chamber, the frit was slightly stiffened by the addition of flint.

On drawing, the sorter divided the bricks into coarse, medium and fine, depending upon the size of the speckle. The best effect was given by the heavy blotches.

In burning a number of kilns of red mottled brick, a little trouble was experienced by sticking, no sand being used in setting. It is preferable to use a red-burning sand on the faces of these bricks. as a little overfiring causes sticking.

The residences built of these brick were very pleasing in

appearance. For Colonial or old English styles of architecture, the red mottled brick are especially suited, and the effect in houses of this type would be very desirable. Red or black mortar of course should be used.

Another use to which the black frit can be put is the production of black headers for use in Flemish bond. The frit is made up into a slip and painted on the green bricks with a brush, or it may be atomized on.

THE CONSTRUCTION OF A WHITE WARE POTTERY.

Discussion by L. E. Barringer, Schenectady, N. Y.

As Mr. Watts states in concluding his paper on "The Construction and Equipment of a White Ware Pottery," the suggested plans and equipment would require modification to suit the location and local conditions. Apart from such special considerations, however, there are several points in the plans and paper open to discussion along the lines of general convenience and economy.

The arrangement of the raw material bins, as proposed by Mr. Watts, is such as to necessitate conveyance to all except two of the bins, and an additional haulage or conveyance to the blungers. A better plan would be to build these bins in a single row running along one side of the slip house, so that the clay, flint, spar, etc., could be thrown or dumped direct from the car into the proper bin. The bins thus arranged would also render charging of the blungers more convenient than otherwise. The general idea of such an arrangement is shown in the accompanying sketch. By also slightly rearranging the saggar shop and boiler room, as shown, the railroad tracks could be brought conveniently past the bins for the saggar clays and the coal bin for the boiler house. The boiler room in Mr. Watt's plans stands some distance back from the track. By this modification we would thus have the coal bins for both kilns and boilers, the saggar clay bins and the ware material bins all convenient for unloading direct from the cars. This would also prove a more compact arrangement, and bring several projecting wings into one building.

Mr. Watts recommends a separate room for placing and saggar storage, to get this work away, he says, from "a dirty, smoky kiln room." No reason is given why this condition should exist in the kiln room, but anyone who has visited many large potteries will admit that in ninety-nine cases out of a hundred the kiln room arrangement is clumsy and inconvenient, and *is* usually, dirty and smoky. In some of the largest potteries in the

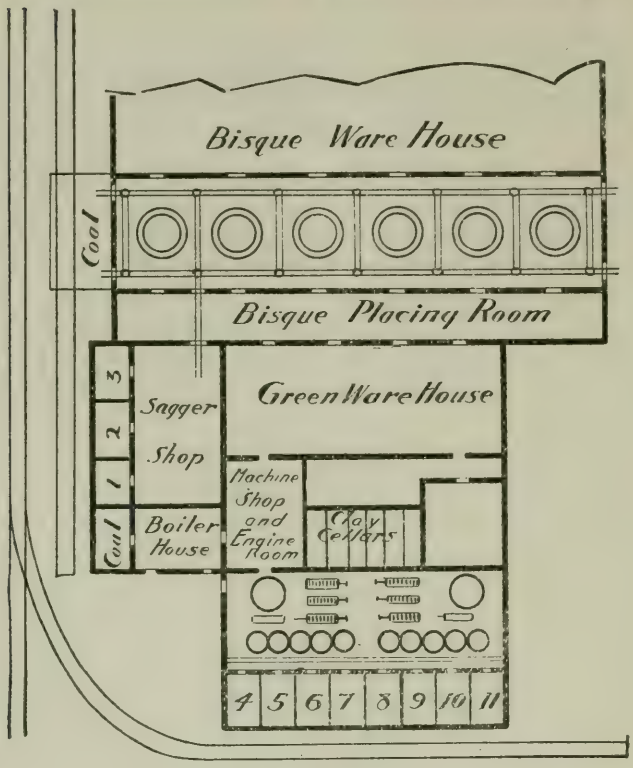


Fig. 1.

country in going through the kiln room one must pick his way around piles of saggars and placing benches scattered carelessly about, over coal and ash heaps, and in some cases even broken saggars. Not only kilns which are under fire are surrounded by a ring of coal, but if by any chance there has been coal left over when a kiln was fired off there it stands until the next burn. This persistent practice of potters of dumping coal around a kiln to be fired is one of the chief reasons for the prevalent untidiness in the kiln room. Mr. Watts not only recommends this plan of distributing fuel, but for the purpose proposes a system of elevated tracks which would probably add to the complications in the kiln room. With a simple system of surface tracks around the kilns it is possible to maintain a most orderly and decently clean kiln room in any pottery. These tracks should extend to

the coal bins; and turn-tables properly placed enable a car to be run entirely around a kiln. The coal is brought from the bins on cars and thrown from these cars direct into the kiln furnaces, no coal whatever being dumped on the floor. A side-drop car of about one ton capacity is a convenient size to handle, and will hold sufficient fuel for from several to a dozen firings, depending on the condition of the fires. There should be at least one car for each two kilns. The car system can also be used to remove ashes, clinkers, broken ware and saggars. The arrangement in the case of the pottery designed by Mr. Watts would be as shown in the sketch. The branch leading to the saggar shop is for the purpose of conveying the broken saggars to that point for grinding into grog. The General Electric Co. uses this system of fuel handling in its porcelain shop at Schenectady, and the kiln room is far beyond the average in cleanliness and order. Some of the ware is glazed within fifteen feet of one of the kilns, no partition whatever existing between the kiln and the glazing apparatus.

In discussing raw materials, Mr. Watts proposes buying and grinding silica sand as a cheap substitute for ground quartz rock. This is probably not only feasible, but would prove economical. Recently I have had occasion to examine a number of sharp silica sands such as are used in making steel castings, and have found that many of such sands run as high in silica as does quartz rock, and when ground fine give a clean white powder. Below are given the silica and iron content of some of these sands:

		SiO_2	Fe_2O_3	
1	Sand from Williamstown, N. J...	97.71	0.8	
2	Sand from Cedarville, N. J.....	95.49	0.69	yellowish
3	Sand source unknown.....	94.68	1.3	very yellow
4	Sand from Cleveland, O.....	97.85	0.4	slightly yellow
5	Sand from Crosskeys, N. J.....	99.25	0.4	sharp clean sand
6	Sand from near New York City..	99.50	0.3	sharp clean sand
7	Sand from Philadelphia, Pa.....	99.35	0.3	sharp clean sand

A sand that contains less than 98 per cent. SiO_2 or more than .5 per cent. Fe_2O_3 is not likely to prove a satisfactory material for the purpose. Either sand No. 6 or No. 7 in the above table would probably prove a very satisfactory substitute for

quartz rock. As to whether it is more difficult or not to grind sand than quartz rock which has been heated and chilled is a question which must be solved by trial, but there is no reason to suspect any great difference in this respect. But I have been told by a flint and spar dealer, who has ground more or less sand, that it requires six hours to grind a ton charge of sand and only four hours for a ton charge of quartz rock to the same fineness.

In connection with the idea of using an absorbent material interposed between the plates and cloths of the filter press, it must be noted that while the press may be filled in less time, the introduction of these cushions must necessarily reduce the actual space capacity of the press. The felt or other material used, to be effective, must be reasonably thick, and the capacity of each chamber will be reduced by two thicknesses of the material used. This may reduce the weight of clay mixture obtained per filling of the press considerably, and the difference in this respect and the increase in number of fillings per day must be taken into account when estimating the advantage of this scheme. The saving on sack wear is of more importance in iron presses than in wooden ones. As a rule cloths wear but slowly on presses provided with wooden plates. This idea of an absorbent, yielding, intermediate layer between cloth and plate has been patented by Mr. Fred Locke, of Victor, N. Y.

The glaze, Mr. Watt says, should all be ground in ball mills, but in some cases I think the glaze pan will be found to be advantageous and economical, and preferable to ball mill. If but one or two glazes are in use as in porcelain or white ware factories, the pan has the advantage of continuous operation, and need not be stopped for charging or discharging. It can be used as both grinder and agitator, and the glaze supply can be pumped from the pan direct to the glazing room as needed. When the glaze gets low in the pan more is fed into the top without stopping the machine. The glaze pan is also a very efficient grinder. Large particles sink to the bottom of the pan where they come under the influence of the grinding action of the revolving crusher blocks, while fine particles are kept in suspension by the motion of the slip.

NOTES ON STONEWARE GLAZES.

BY

S. Geijsbeek, St. Louis, Mo.

In describing the results of a number of stoneware glazes made as tests by different parties, Purdy[1] states that the Robinson-Merrill Pottery Co., of Akron, Ohio, use Kentucky ball clay for their regular glazes, while their chemist, Mr. Shoemaker, uses China clay, and gets better results with this particular China clay, without stating what particular kind this China clay is.

Further on in his notes on this subject, Purdy explains the opaqueness of certain glazes, and without actually stating the fact, his remarks seem to express the idea that the trials made by Shoemaker with this particular china clay are more opaque than the trials made by the Macomb Pottery Co., where they are using English ball clay in the glaze. Both sets of trials were made from the same formula and fired nearly at the same temperature.

Not knowing the particular china clay Shoemaker uses, but which I presume is one of the regular American brands, I will say that the increased opaqueness of his trials is, in my opinion, due directly to the substitution of china clay for English ball clay.

I find several places in our transactions where china clay is substituted for ball clay, without paying any attention whatever to its chemical formula or analysis. I find our members using the common formula and equivalent weight of Al_2O_3, 2 SiO_2, 2 H_2O for both. In such a case we will find more fusibility with the ball clay glaze, than with the kaolin glaze. It has been my experience that china clay gives whiter glazes than the same glazes mixed with ball clays.

The following formula was used for an actual test as to the color of different brands of kaolins and ball clays, using the common formula of Al_2O_3, 2 SiO_2, 2 H_2O for both:

$$\left.\begin{matrix} 0.20\ K_2O \\ 0.20\ CaO \\ 0.50\ ZnO \\ 0.10\ BaO \end{matrix}\right\} \quad 0.5\ Al_2O_3,\quad 2\ SiO_2$$

(1) Transactions American Ceramic Society, Vol. V, page 163.

In the trials here shown, each letter represents a different clay.

A. English China Clay No. 7, (Golding & Co.).
B. Georgia Kaolin (Mandle).
C. Florida Kaolin (Edgar).
D. Tennessee Ball Clay (Mandle).
E. English Ball Clay (Golding & Co.).
F. Missouri Ball Clay (Ill. Mineral Milling Co.).

These trials were all burnt at the same time in a muffle kiln at Seger cone 6. You will notice that all kaolin samples are whiter and better in color than any of the ball clay samples.

NOTES ON ENGOBES.

BY

S. Geijsbeek, St. Louis, Mo.

In his paper "A method for making enameled brick,"[1] Barringer makes the comment that flint is a very valuable agent for engobe purposes. While I am indebted for the suggestion thus advanced, I think Mr. Barringer should be a little more cautious in giving advice without more knowledge of the working conditions.

In the first place, the experiments which I mentioned in my paper on stoneware engobes[2] were all made on green clay, while Barringer has only worked on biscuit bodies.

The difference between fitting an engobe on biscuit and on green bodies is just as great as the compounding of glazes for green and biscuit ware. His statement "To coat drypress brick in the green state with a glaze or enamel is a delicate process, entailing much loss and poor quality of product,"[3] shows that he realizes that the conditions under which I had to work to make a satisfactory engobe on green stoneware were difficult.

On a biscuit body, we start out with a ground layer for the engobe which has already reached its final stages. It is no longer green clay with all its treacherous properties. It has attained its full shrinkage, it does not disintegrate when moistened with water or glaze. It can be handled without fear of breaking or chipping. Its chemical changes from green clay to burnt ware have all taken place. In fact, it is an entirely different material from green stoneware. It is a biscuit body in the full meaning of the word, be it pottery or brick.

Now, let us see what we have when green stoneware is used for a ground layer for an engobe. We have a body which can be in various stages of dryness. It can be wet or green, leather hard or bone dry. It is clay in green state, as it is commonly called. It has yet to get its full shrinkage, it may be that even its drying

1 Transactions American Ceramic Society, Vol. V, page 265.
2 Ibid, page 48.
3 Ibid, Vol. V, page 257.

shrinkage has not fully taken place yet. It has to go through the various stages to get its chemical changes from green clay to burnt ware.

An engobe on biscuit body has to be so compounded that its shrinkage should be nothing, because the body on which it is applied does not shrink any more. An engobe for stoneware has to shrink at the same rate as the shrinkage of the stoneware body on which it is applied.

In the first case we need a compound high in flint to keep its shrinkage down, while in the second case we need a compound of entirely different nature. What this nature should be, I have endeavored to state in my former paper. Practice has shown that an engobe high in flint for green stoneware always has the defect of lifting.

The next point to which Barringer objects is the shifting of clays. Long years of practical experience shows that shifting clays for body purposes is a general rule among whiteware potters. A better and more reliable color in whiteware is obtained by using several kinds of clay in place of using only one kind. In making an engobe on greenware, we have to use some plastic clay, and as it is hard to get pure white-burning plastic clays, we have to add some white-burning kaolins, which are not so plastic. In the compounding of an engobe for green ware, the use of more than one clay will bring quicker results, as my paper on stoneware engobes explained, than by using only one clay and non-plastic materials for shrinkage purpose. Theoretically, the use of one clay may fill ideal purposes, but my long experience, in the engobe line especially, has taught me that shifting clays goes a long way to obtain satisfactory results.

In tabulating his experiments, Barringer uses the term "China clay" without specifying the source. In my paper on stoneware engobes where I mentioned the materials used,[1] I specified the different brands of kaolins, as the physical properties of kaolins are not all alike. The results obtained show that by using only the general term "China clay" as Barringer does, misleading conclusions might be reached. In scientific papers, it is certainly to be expected that we state distinctly how work has been done, as we all know that ceramic materials, even where

1 Transactions American Ceramic Society, Vol. IV, p 51.

known under a common name, generally vary somewhat in composition. It should be our aim to express ourselves as plainly as possible, and to remove the suspicion of the secrecy which hovers around Ceramic receipts.

Barringer states further that he uses a 5 per cent. sodium carbonate solution in the engobe, to hold it on the body, and his only reason for doing so, is that it is a common practice among stoneware people. Stoneware people are apt to use preventatives, without knowing the cause of the defect they are trying to overcome; in addition, they are always working on green ware, and never on biscuit bodies. I judge that the use of 30 per cent. of flint in this engobe was causing trouble, even on a biscuit body, or Barringer would not have resorted to soda to make its engobe stick.

ON THE CHEMICAL COMPOSITION AND REFRACTORINESS OF SOME AMERICAN FIRE-BRICK.[1]

BY

R. F. WEBER.[2]

The relation between the chemical composition and the refractoriness of fire-brick has long attracted the attention of fire-brick manufacturers and those interested in their use, and yet but little systematic work has been done along this line, especially in this country. Analyses of fire-brick have of course been made for years, but fire tests of the bricks, except the tests of durability in practical use, have usually been wanting. A number of tests and analyses of foreign fire-bricks have been published, but very few have appeared in the United States, and even in the foreign literature the references and facts are more or less scattered. The most elaborate piece of systematic foreign work in this line is that by Dr. Jochum[2], and for purposes of comparison this will be referred to later.

In the United States, perhaps the most detailed piece of work and one of the earliest, was that done by F. Platt, for the Pennsylvania Geological Survey, in 1876[3]. His investigation consisted of the analysis and heat tests of twenty-one bricks, the latter being made in an experimental shaft furnace, at Harrisburg. All the bricks were more or less affected at the temperature reached, but there was no means at hand for measuring the degree of heat. That it was considerably higher than the melting point of steel was proved by experiment, but the exact temperature at which individual bricks fused could not be ascertained. Hence comparisons affect only the series tested. The next comprehensive investigation in this line is found in the New Jersey Geological Survey Report on Clay Deposits, in the Report of the State Geologist for 1880. This report, however, deals chiefly with fire-clays; analyses and refractory tests being made of 123 clays, kaolins, feldspars, and fire-sands. Here, again, there was no

1 A thesis prepared in Cornell University, Ithaca, N. Y., under direction of Dr. Heinrich Ries.

2 The writer takes this opportunity of acknowledging his indebtedness to Professor H. Ries, for suggestions made during the course of the work.

3 Tonindustrie-Zeitung, April 30, 1903.

4 Second Geological Survey of Pennsylvania, Report MM, p. 270.

accurate means of measuring the temperature, the only measurement of the intensity of the heat obtained being from the fusing point of platinum. Chief among the recent work in this field is that of Dr. H. Ries, published by the New Jersey Geological Survey, brief abstracts of which appeared in the Transactions of the American Institute of Mining Engineers[1]. The main point noted in this work was that the fusibility of the New Jersey brick was influenced largely both by the silica percentage, and by the texture, it being found that the fusion point of almost any of the New Jersey fire-bricks could be reduced four or five cones by grinding the brick sufficiently fine to pass through a 100 mesh sieve.

In the present paper there are presented the results obtained in testing a series of fire-brick from different parts of the country, in order to determine their chemical composition, their refractoriness, texture and the relation of the three.

Tests that have been made in other countries and also in this country, indicate quite clearly that the variation in refractoriness of fire-bricks depends on both the chemical composition and the texture, although the importance of the second of these two factors is not always recognized. In the work to which this paper refers, examples of 44 fire-brick were taken, representing different localities in the United States. The fusion point of each of these was determined as nearly as possible and the partial chemical analysis made, lack of time preventing the carrying out of a complete analysis. It is felt, however, that the analysis even in its incomplete form is sufficiently valuable for purposes of discussion. The substances determined were total SiO_2, Al_2O_3, Fe_2O_3 and TiO_2. The difference between the sum of these and 100 represents the total percentage of alkaline earths and alkalies. The importance of the estimation of titanic acid has been pointed out by many, including Seger, Vogt[1], and Ries[2].

The methods of analysis will first be considered, then the fire tests, which in turn will be followed by a discussion of the results obtained. Lastly, a number of foreign analyses and fire tests are given and discussed, and comparisons made with the American fire-bricks.

1 Notes on the New Jersey Fire-Brick Industry, XXXIV, p. 254.
1 Tonindustrie-Zeitung, 1903, No. 77, p. 1247.
2 Op. cit.

METHODS OF ANALYSIS.

In the main, the methods used in this work were those suggested by Richardson and Hillebrand for cement analysis[1]. A "fair sample" of the brick (usually about 60 gm.) was first obtained, as in assaying, and this was ground to pass a 100 mesh sieve. It was then sampled down to from 3 to 5 grams, and a portion of this, after grinding in an agate mortar, was taken for analysis. This was fused in the usual manner with sodium and potassium carbonates. Double evaporation was made for silica, and double precipitation of iron and alumina, as recommended in the work already cited. The combined iron and aluminum oxides were fused with $KHSO_4$ in the crucible containing the residue from the hydrofluoric acid correction for silica, the melt taken up with hot 5% sulfuric acid, the iron reduced by H_2S and determined, after filtering off the precipitated platinum, by titrating with $KMnO_4$. The titanic acid was determined by Weller's method, as advocated in Bulletin 176 of the U. S. Geological Survey, and alumina by difference. The apparatus used for the colorimetric determination was modeled somewhat after that described by Cameron & Failyer, of the Bureau of Soils, U. S. Department of Agriculture[2]. Instead of having a cylinder with side arm and tubing, however, two Hehner cylinders, with glass stoppered side arms, were used and found very satisfactory. In connection with the determination of titanic acid, it may be mentioned that considerable difficulty was experienced in getting the strength of the standard solution. The titanic acid (obtained from a German firm) used to make up the solution, was found altogether too impure to allow of a definite amount being weighed out, and the strength of the solution calculated, so recourse was had to a gravimetric method. Several were tried, the one finally decided upon as the most satisfactory being that of Gooch, described in "Principles and Methods of Rock Analysis," by Hillebrand[1]. Even by this method, it was only after repeated fusions that the TiO_2 was obtained pure, difficulty being found in freeing the residue from manganese and iron.

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1 Journ. Society of Chemical Industry, vol. 21, (1903) p. 30.

2 Journ. Am. Chem. Soc. 25 (1902) p. 1066.

1 U. S. Geological Survey, Bulletin 176 (1900) p. 71.

FIRE TESTS.

The fusion point was determined by testing pieces of the fire-brick in the Deville furnace. Unless a brick is exceedingly fine grained the entire mass does not fuse at once, nor does even a large part of it do so. In any brick there are usually found a large percentage of very coarse grains which range anywhere from one to five mm. in diameter, these grains being either angular or rounded, and consisting generally of either flint, clay, quartz, or grog (*in German, chamotte*). Surrounding these is a more or less fine grained matrix. The matrix of the brick usually fuses first, and if the percentage of the matrix in the brick is great, the brick may lose its shape rapidly, but if the percentage is small the brick may hold its shape for some time. The fusion point of the bricks was generally taken as that point at which the matrix, and in some cases the larger grains, became sufficiently softened to cause the brick to lose its shape. In many instances the larger grains still retain their identity even after the brick softens down to a more or less viscous mass. In judging the refractoriness of the bricks, therefore, it should be remembered that the fusion point as here given does not necessarily mean that the brick is viscous at that point:—in fact, in most cases the bricks will stand a higher temperature before becoming thoroughly viscous.

ANALYSES AND FUSION TESTS.

Having outlined the methods of examination followed, it remains to present the results obtained. The table on pages 217-220 gives the analysis, cone of fusion and texture of the fire-bricks examined, and is given at this point so that the results can be more clearly discussed. The table is arranged according to the degree of refractoriness, those bricks having the highest fusion point being given first. Where several bricks have the same fusing point, they are arranged in descending order according to the percentage of fluxes—the sum of the iron oxide, titanic acid, alkaline earths and alkalies. The titanic acid is placed among the fluxes, as it has been shown by recent investigations that percentages of but two or three per cent. added to a high grade kaolin lowered its fusing point two or three cone numbers[1].

1 H. Ries, Trans. Am. Inst. Min. Eng., Albany Meeting, Feb., 1903. Vol. xxxiv, p. 254. See also forthcoming report on clays, N. J. Geol. Survey.

It should be remarked here that the cone of fusion was not exactly determined for those bricks having a refractoriness of less than cone 26-27. These bricks were thoroughly fused at 27, but at just what point the matrix fused sufficiently for the brick to lose its shape (which, as previously stated, was taken as the fusing point) was not ascertained. From all appearances, however, the fusion took place probably somewhere between cone 24 and 26. See Table I, pages 217-220.

Inspection of this table shows two points standing out preeminently. 1st, the variation in the fusion point, and 2nd, the generally high percentage of total fluxes. Out of the 44 bricks tested, it will be noticed that only four will stand at cone 33, and that seven fuse below cone 27. Approximately one-half of the total number fuse below cone 30. There are more bricks corresponding to cone 31 than to any other one cone.

As to the second point; the percentage of total fluxes seems in many cases very high. The generally accepted idea is that both fire-clays and fire-bricks should run low in impurities, preferably under 3 or 4%, and yet here we find one of the best bricks with a flux percentage of over 10%. Moreover, it will be noticed that in all the bricks with a refractoriness of cone 30 or above, (with the exception of No. 5, a silica brick) the minimum flux content is 4.88%, the maximum 12.40%, and the average about 8.60%. This high percentage seemed so remarkable that a careful search among published fire-brick analyses was made, and it was found that in a number of cases the total fluxes is high, even in quite refractory bricks, as will be shown later. Moreover, in most analyses the titanic acid was not estimated, and consequently the alumina appears too high and the total fluxes too low, by the amount of TiO_2 present. The fact that TiO_2 is absent from few clays is now generally recognized[1], and its influence on the fusibility of a clay has been mentioned above[2], [3]. Concerning the amounts of TiO_2 found in these bricks, No. 6 alone is noteworthy. In this the percentage, (5.54), is higher than found in any published analyses of American fire-clays or fire-bricks, but Odernheimer[4] cites clays from the Duchy of Nassau with a titanic acid

1 Tonindustrie-Zeitung, 1903, pp. 1247, 1475.
2 ibid, 1883, p. 243.
3 op. cit.
4 Tonindustrie-Zeitung, 1903, p. 1475.

content of from 2.30 to 4.60%, and Kovar[1] found clays containing from 1.33 to 10.04% of TiO_2. Of the American clays reported, two from Clinton Co., Pa. show the highest percentages of titanic acid, viz. 400% and 3.36%[2].

It will be noticed that with two exceptions (which will be spoken of later) none of the bricks fusing at or above cone 30 have a silica content of over 60%, while in the case of those fusing below this cone, the percentage of silica rarely falls *below* 60. This, notwithstanding the fact that many of the more refractory bricks have an extremely high percentage of total fluxes.

In order to make comparisons and to present these facts more graphically than can be done by a mass of figures, the analyses and refractoriness of the bricks have been plotted on co-ordinate paper, whereby curves may be drawn which will materially assist in the discussion of results.

DISCUSSION OF RESULTS.

The points previously mentioned are brought out and accentuated in Plate I. Among the facts to be noted in this plate are the following: A line drawn vertically at No. 21 includes on the left all bricks fusing above cone 30, and on the right, those fusing below that cone. It will be noticed that to the left of this hypothetical line, the 55% line would form a fairly good mean for the silica content, while to the right, the mean would run pretty close to the line marked 65%. With certain exceptions then, it seems that the silica content furnishes a rough estimate of the refractoriness of a fire-brick. It is further apparent, at the very start, that the percentage of total fluxes cannot form an exact basis for judging the refractoriness.

Considering the chart as a whole, if we construct a mean curve for the fusion points and a second curve for the silica content, there is a general rise for the latter accompanying the fall in the fusion point, a notable exception being No. 4, which is a silica brick. If there were no fluxes present, we should, of course, look for an ascending alumina curve as the silica curves descend. This is found to be the case in general,—the alumina curve being the image, as in a mirror, of a silica curve. The exceptions, as

1 Sprechsaal, 1891, p. 106; Tonindustrie-Zeitung, 1903, p. 1247.
2 Second Geol. Survey of Pennsylvania, Report MM. (1867-8).

TABLE I.

Number	Percentage Composition.				Earths and Alkalies by Difference.	Sum of Fluxes.	Cone of Fusion.
	SiO_2	Al_2O_3	Fe_2O_3	TiO_2			
1	51.59	38.26	1.84	1.97	6.34	10.25	32-33
2	54.90	38.19	2.18	1.55	3.18	6.91	32-33
3	53.05	41.16	2.65	1.80	1.34	5.79	32-33
4	93.57	2.53	0.62	0.27	3.01	3.90	32-33
5	44.77	43.08	2.78	2.54	6.83	12.15	31-32
6	68.70	20.75	1.20	5.54	3.81	10.55	31-32
7	49.44	40.94	3.68	2.23	3.71	9.62	31-32
8	52.06	40.27	3.47	1.28	2.92	7.47	31-32
9	56.14	39.81	1.84	1.08	1.96	4.88	31-32
10	53.45	34.15	3.53	1.89	6.98	12.40	31
11	56.09	31.78	3.16	1.93	7.04	12.13	31
12	54.41	36.20	2.10	2.13	5.16	9.39	31
13	50.31	41.21	2.55	2.45	3.48	8.48	31
14	55.90	35.71	2.34	2.17	3.88	8.39	31
15	50.26	41.44	2.02	1.64	4.64	8.30	31
16	55.97	36.22	3.44	1.57	2.80	7.81	31
17	57.28	35.23	2.64	1.25	3.60	7.49	31
18	50.82	43.51	1.71	1.80	2.16	5.67	31
19	54.71	33.68	2.55	2.02	7.04	11.69	30-31
20	59.88	33.35	3.31	1.37	2.09	6.77	30-31
21	50.38	39.81	2.34	1.81	6.66	10.81	30
22	65.66	28.77	2.18	1.14	2.25	5.57	30

TABLE I.

Locality.	Texture.
St. Louis, Mo.	Fairly uniform, angular, flint-clay particles, constituting body of brick. Largest pieces, 5-6 mm. in diam. White.
Louisville, Ky.	Coarse grained; angular pieces of flint-clay, as large as 9 mm.; average 4-5 mm. Light Buff.
Benezet, Pa.	Coarse, angular, flint-clay particles, varying from 1-5 mm. in diam. Average 4-5 mm. Buff.
Canon City, Colo.	Fine grained quartz particles, largest 2-3 mm. in diam. White.
Louisville, Ky.	Medium grain; flint-clay particles fairly uniform in size, 3-4 mm. Light Buff.
Staten Is., N. Y.	Coarse grain; quartz particles, 4-5 mm. in diam., forming about 50 per cent. of brick. White.
Monroe, Pa.	Large, angular pieces of flint-clay scattered irregularly throughout brick. Largest 12 mm., average 6 mm. Buff.
Denver, Colo.	Medium grain; quartz particles, 1-2 mm. in diameter, abundant. Speckled gray-white.
St. Louis, Mo.	Angular flint-clay particles, fairly uniform in size. Largest 5-6 mm. Light Buff.
Fullerton, Ky.	Coarse; large, angular, flint-clay particles, 4 mm., constitute body of brick. Buff.
Fullerton, Ky.	Like 10, but average size of particles slightly greater.
Olive Hill, Ky.	Flint-clay particles, 2-10 mm. in diameter, (av. 5 mm.), scattered throughout reddish-brown matrix.
Olive Hill, Ky.	Medium grain; angular flint-clay particles, 1-3 mm. in diameter, forming about 50 per cent. of brick. Buff.
Olive Hill, Ky.	Large, angular particles of flint-clay, varying from 2-10 mm. in diam, forming 60 per cent. of brick. Buff.
Ironton, O.	Coarse; contains many flint-clay (and perhaps 3 mm. quartz) particles. Average diameter 4 mm. Cream.
Cincinnati, O.	Largely composed of large, angular, flint-clay particles. Average diameter 7 mm. Buff.
Portsmouth, O.	Flint-clay particles, average 2-4 mm. in diameter, throughout red-brown matrix.
Ironton, O.	Coarse; large quartz particles. Average 4 mm. in diameter. Cream.
Olive Hill, Ky.	Medium-grain, flint-clay particles. Largest 4 mm., average 1-2 mm., forming 50-60 per cent. of brick. Buff.
Cincinnati, O.	Large, angular pieces of flint-clay constitutes greater part of brick. 1-10 mm. in diam. Average 5 mm. Buff.
Clearfield, Pa.	Medium-grain, angular flint-clay particles, average 3-4 mm., forming about 60 per cent. of brick. Buff.
Stevens Pottery, Ga.	Not abundant. Quartz grains, small to 6 mm. in diam., in an even, close grained matrix. Cream.

TABLE I—Continued.

Number	Percentage Composition.				Earths and Alkalies by Difference.	Sum of Fluxes.	Cone of Fusion.
	SiO_2	Al_2O_3	Fe_2O_3	TiO_2			
23	59.67	33.28	1.98	1.51	4.06	7.55	29-30
24	75.78	21.81	1.39	0.77	0.25	3.33	29-30
25	60.69	28.01	2.51	1.17	7.62	11.31	29
26	72.47	19.78	1.67	0.81	5.27	7.75	29
27	52.44	40.26	3.57	1.90	1.83	7.30	29
28	72.53	20.88	1.69	1.02	3.88	6.59	29
29	69.69	25.72	1.90	1.37	1.32	4.59	29
30	72.94	15.95	2.81	1.87	6.43	11.11	28
31	67.61	25.66	2.42	1.55	2.76	6.73	28
32	77.66	9.87	1.29	3.89	7.29	12.47	27-28
33	54.81	34.58	3.39	1.51	5.71	10.61	27-28
34	60.99	24.34	2.84	1.92	9.91	14.67	27
35	69.06	21.67	3.23	0.99	5.05	9.27	27
36	77.01	15.29	1.89	0.93	4.88	7.70	27
37	68.99	24.78	2.00	1.12	3.11	6.23	27
38	75.54	14.50	2.72	2.13	5.11	9.96	26-27
39	74.58	16.41	3.06	1.31	4.67	9.04	26-27
40	61.28	27.13	2.90	1.37	7.31	11.58	26
41	74.83	16.40	3.26	0.77	4.74	8.77	26
42	67.19	25.05	2.83	0.71	4.22	7.76	26
43	60.76	31.66	5.67	1.58	0.33	7.58	26
44	60.58	32.49	2.25	1.69	2.99	6.93	26

TABLE I—Continued.

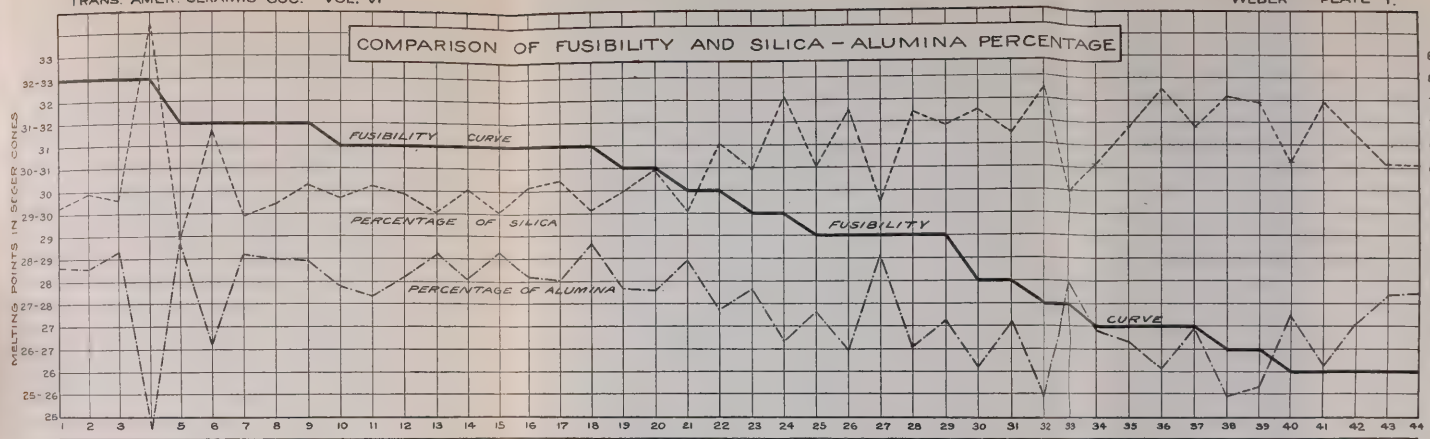
Locality.	Texture.
Chicago, Ill.	Large, white, angular, flint-clay particles, throughout a brownish matrix. Largest 8-9 mm. Average 4 mm.
Athens, Tex.	Fine grain, but wiht a few large particles of grog. Nearly White.
Chicago, Ill.	White flinty particles, 2-5 mm. in di., throughout a reddish-brown matrix, and forming 20 per ct. brick. Brown.
Canon City, Colo.	Medium-grain rounded, quartz particles, 1-2 mm. in diameter. Light Cream.
Clearfield, Pa.	Coarse, large, angular flint-clay particles, largest 10mm., average 4 mm., form about 70 per cent. of brick. Buff.
Canon City, Colo.	Small, angular flinty particles. 2-3 mm. in diameter. Nearly White.
Akron, O.	Coarse; a large portion of brick is flint-clay, varying from small to 9 mm. in diam. Average 4-5 mm. Buff.
Ashville, N. C.	Fine grained, with occasional large quartz particles. One 19x9 mm., another 9x6, but mostly 5-6. Cream.
Akron, O.	Medium grain; small quartz particles, quite uniform in size (1-2 mm.), generously distributed. Buff.
Staten Is., N. Y.	Fine; only now and then a quartz grain of appreciable size. Buff.
Monaca, Pa.	Coarse; largely composed of white to nearly black flint-clay, fairly uniform in size. Average about 4 mm. Buff.
Layton, Pa.	Medium grain; large particles made up of quartz grains, fairly uniform in size, about 2 mm. Buff.
Hillsdale, Ind.	Very fine grain; few coarse particles. Light Buff.
Hillsdale, Ind.	Fine grained; some quartz particles, 3mm. in diameter, but these form small percentage of brick. Cream.
Akron, O.	Coarse; large, angular flint-clay particles, fairly uniform in size (3-6 mm.), forming 40-50 per cent. of brick. Buff.
Carbon Cliff, Ills.	Medium grain; small quartz grains (1-2 mm.) and some flint-clay, forming about 40 per cent. of brick. Buff.
Carbon Cliff, Ills.	Rather coarse; about 40 per cent. of brick of coarse particles, some of 9 mm. in di., but av. about 3-4 mm. Buff.
Monaca, Pa.	Fine grain; small, white, flint-clay particles, not over 2 mm. in diameter, and not abundant. Buff.
Monaca, Pa.	Medium grain; pieces of quartz with pinkish color and angular flint-clay particles. About 3 mm. in diam. Buff.
Alabama	Fine grain, even texture; few coarse particles. Brown.
Cayuga, Ind.	Fine grain; some particles as large as 1-2 mm. in diameter. Buff.
Louisville, Ky.	Angular dark colored flint-clay particles, maximum size 5 mm., throughout a reddish-brown matrix.

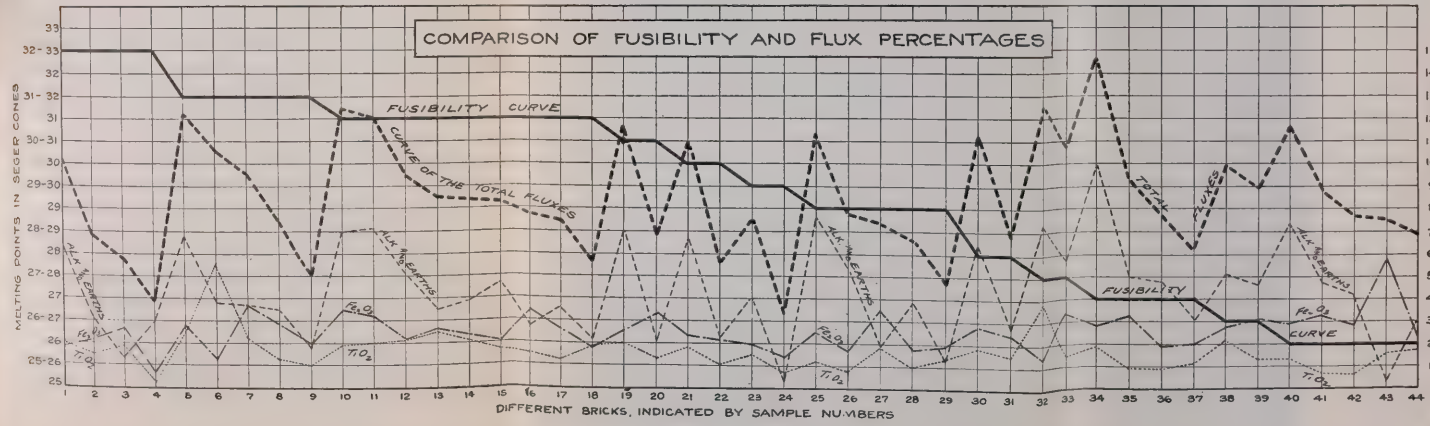
Nos. 10 and 32, are obviously due to the high percentage of total fluxes. If a mean curve were drawn from the total fluxes, it would be an exceedingly irregular one. The actual curve for sum of fluxes brings out a point already referred to, viz., the high percentage of total fluxes even in the better grades of brick.

Where the brick shows a fair refractoriness in spite of a moderately high silica percentage and a high content of total fluxes, it is probably due to the fact that much of the quartz, which is a powerful fluxing element, is bound up in grains sufficiently coarse to prevent active fluxing action. This is well illustrated by Nos. 25 and 40. The percentages of the various elements as shown by the analyses are nearly alike, yet we find that the one has a fusing point of less than cone 26, while the other does not fuse until cone 29 is reached. Referring to the table of textures, it will be noticed that No. 40 is of fine grain, containing white flint-clay particles, and those small, while No. 25, on the other hand, contains quite a percentage of white flinty particles, averaging from two to five mm. in diameter. Even more strikingly is this point of texture exhibited in No. 6. Glancing along the silica and alumina curves, we find No. 35 with almost identically the same amount of those constituents, while with regard to the fluxes, the difference is in favor of No. 35. And yet we find No. 6 fusing at cone 31-32, and No. 35 at cone 27. The latter, however, is of very fine grain, with few coarse particles, whereas probably 50% of the former is composed of quartz particles, 4-5 mm. in diameter. Comparison of Nos. 26 and 35, 37 and 42 affords further evidence concerning the influence of coarseness of grain on fusibility. In some cases the high silica content combined with a high fluxing percentage (as in Nos. 34, 38 and 39) is sufficiently great to reduce the fusion point even though the brick contains many grains of medium size.

Another interesting point is that the least refractory bricks of those tested are not those containing the highest silica or highest total fluxes, as for example Nos. 42 and 43. These, however, are both of fine grain.

A high content of total fluxes does not necessarily indicate a very low refractoriness, for three (Nos. 5, 10, and 11,) with over 12%, have a fusion point of at least cone 31. The refractor-


COMPARISON OF FUSIBILITY AND SILICA – ALUMINA PERCENTAGE
MELTING POINTS IN SEGER CONES
ULTIMATE COMPOSITION IN PERCENTAGES
FUSIBILITY CURVE
PERCENTAGE OF SILICA
PERCENTAGE OF ALUMINA
FUSIBILITY CURVE


COMPARISON OF FUSIBILITY AND FLUX PERCENTAGES
MELTING POINTS IN SEGER CONES
PERCENTAGES OF FLUXES
FUSIBILITY CURVE
CURVE OF THE TOTAL FLUXES
ALK. & EARTHS
ALK. & EARTHS
ALK. & EARTHS
TOTAL FLUXES
FUSIBILITY CURVE
Fe2O3
TiO2
Fe2O3
TiO2
TiO2
DIFFERENT BRICKS, INDICATED BY SAMPLE NUMBERS

iness of these was no doubt materially assisted by the coarseness of the particles.

That a high silica content exerts a more active fluxing effect than a high percentage of the more fusible fluxes, is apparent from a close examination of this chart. Following the curve of total fluxes, we find that No. 38 has practically the same amount as No. 1. There is little change in the various fluxes, but the increase in percentage of silica is very marked—a rise of 24%. The fall in fusibility can be only partially explained by coarseness of grain, for the texture is much the same, as will be seen on referring to Table I. As No. 1 is high in total fluxes, we should expect that it would be less refractory than one containing less total fluxes, but of the same texture. Such a one is No. 37, which, however, becomes viscous six cones below No. 1. This can only be accounted for by the difference in silica and alumina contents, for the percentage of iron oxide is but slightly greater and that of titanic acid is nearly one per cent. less. With Nos. 39, 40 and 41 also, the silica seems to exercise the chief role in the lowering of the fusion point below that of No. 1. The texture cannot here be appealed to, for both 39 and 41 are similar in this respect. Nos. 8 and 26 also, are of about the same texture and equal percentage of total fluxes, and the difference in refractoriness must be due to the higher silica content of one. A comparison of Nos. 3 and 37 leads us to the same conclusion regarding the greater fluxing action of a high content of silica.

The value of a chemical analysis for judging the refractoriness of a clay has long been a subject of discussion, and the results here obtained seem to emphasize its unreliability for judging the *absolute* refractoriness of fire-brick. A glance at Nos. 36 and 37 will show how little can be told of even the relative refractoriness of two bricks by the chemical composition. Everything in the analysis seems to indicate a greater refractoriness for No. 37 than for 36, and yet their fusion points are the same, even though the texture of No. 37 would also indicate a higher fusing point. In the case of Nos. 27, 32 and 33 the chemical composition is again valueless as regards the reason for the falling off in refractoriness of the bricks, and here, too, fineness of grain is not responsible. In many other cases (as for example Nos. 8, 15 and 18) the only explanation that can be made for the low fusion

point, is on the assumption that as Heintz says[1] the main mass, in highly aluminous bricks, is usually much higher in Al_2O_3 than is the binding agent used, and from this difference it may result that a less highly aluminous brick may stand better than another higher in alumina.

We can see from the foregoing, therefore, that the refractoriness of fire-bricks depends on the total fluxes, the silica percentage and the coarseness of grain, and that the chemical analysis alone cannot be used as an index of the refractoriness except within rather wide limits. In the case of clays, in which there is not such a variation in grain size, it is possible to use a chemical analysis for constructing a formula which indicates much more closely the refractoriness of the material.

FOREIGN RESULTS.

For the consideration of foreign results, Plate II, similar to Plate I, has been prepared. With one exception, (No. x) these are all of foreign fire-bricks or fire-clays, and the locality and source of information is given herewith. Those marked [1] are analyses of German clays used in the manufacture of fire-bricks exhibited at the Berlin Exhibition, of 1896[1]; and those marked with 2 are analyses of fire-brick shown at the exhibition at Dusseldorf[2].

1 Stahl und Eisen, xvii, pp. 63-64.

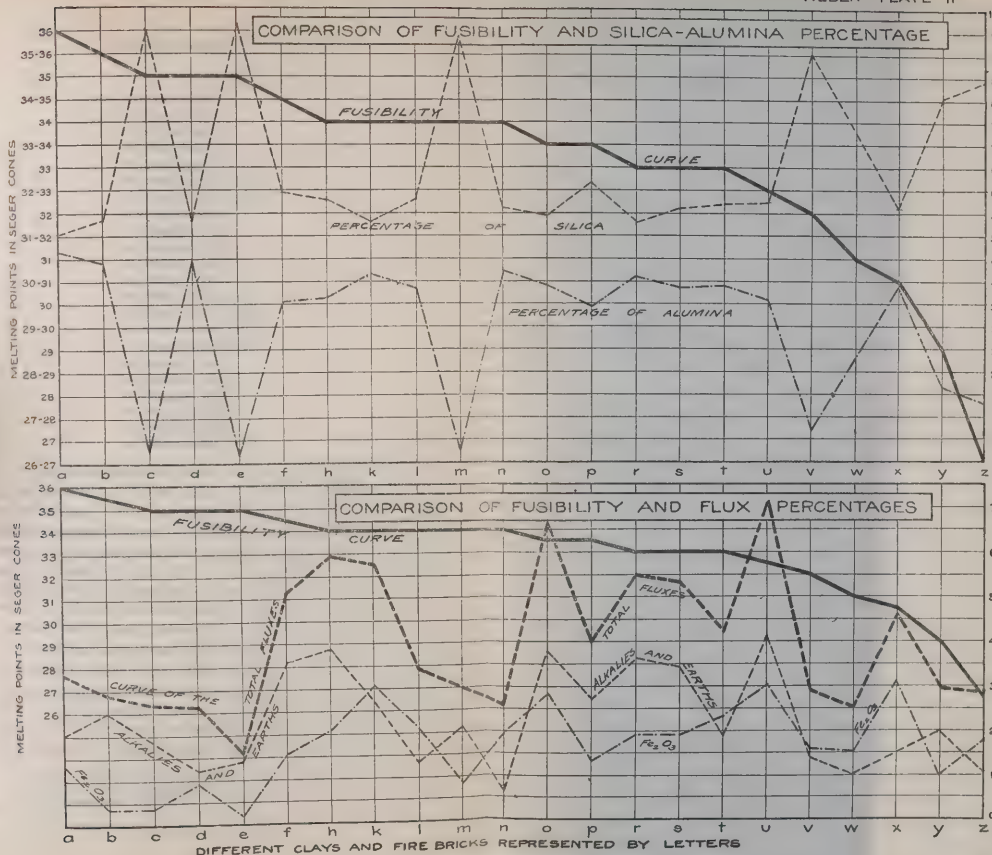

COMPARISON OF FUSIBILITY AND SILICA-ALUMINA PERCENTAGE
MELTING POINTS IN SEGER CONES
ULTIMATE COMPOSITION IN PERCENTAGE
FUSIBILITY CURVE
PERCENTAGE OF SILICA
PERCENTAGE OF ALUMINA
36
35-36
35
34-35
34
33-34
33
32-33
32
31-32
31
30-31
30
29-30
29
28-29
28
27-28
27
26-27
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
a b c d e f h k l m n o p r s t u v w x y z
COMPARISON OF FUSIBILITY AND FLUX PERCENTAGES
MELTING POINTS IN SEGER CONES
PERCENTAGES OF FLUXES
FUSIBILITY CURVE
CURVE OF THE TOTAL ALKALIES AND EARTHS
TOTAL FLUXES
ALKALIES AND EARTHS
Fe2O3
36
35
34
33
32
31
30
29
28
27
26
7
6
5
4
3
2
1
0
a b c d e f h k l m n o p r s t u v w x y z
DIFFERENT CLAYS AND FIRE BRICKS REPRESENTED BY LETTERS

TABLE II.

No. a—Clay slate[1]
b—Clay slate[1]
c—Silica brick[2]
d—Clay from Ifo, Sweden[3]
e—Quartzite[2]
f—Westerwald clay[1]
h—Westerwald clay[1]
k—Kahrlich clay[1]
l—Rhenish clay[2]
m—English Dinas[2]
n—Rhenish clay[2]
o—Baden clay[1]
p—Westerwald clay[1]
r—Westerwald clay[1]
s—Westerwald clay[1]
t—Westerwald clay[1]
u—Baden clay[1]
v—German Dinas[2]
w—Rhenish clay[2]
x—St. Louis clay[4]
y—Bendorf clay[1]
z—Weihersberg clay[1]

It will be noticed that these are nearly all fire-clays, and not fire-bricks, and we do not have to deal, therefore, with such a varied texture. Great variation in the amount of total fluxes is, however, apparent here, as in Plate I, and it is evident from an examination of the plate that a high flux content does not necessarily indicate a clay or brick of low fusibility. No. h, with a total flux content of nearly 6%, has a refractoriness of 34, whereas No. z, with only half the fluxes, fuses at cone 26-27. There is here, however, a great increase in the silica content.

It will be noticed that when above a certain percentage (about 90, here as in Plate I) the silica does not exercise such powerful fluxing action as when it is somewhat lower. This is entirely in accord with the known facts concerning mixtures of kaolin and silica. Up to about 90% of silica, the fusion point decreases as the percentage of silica increases. From that point, however, the

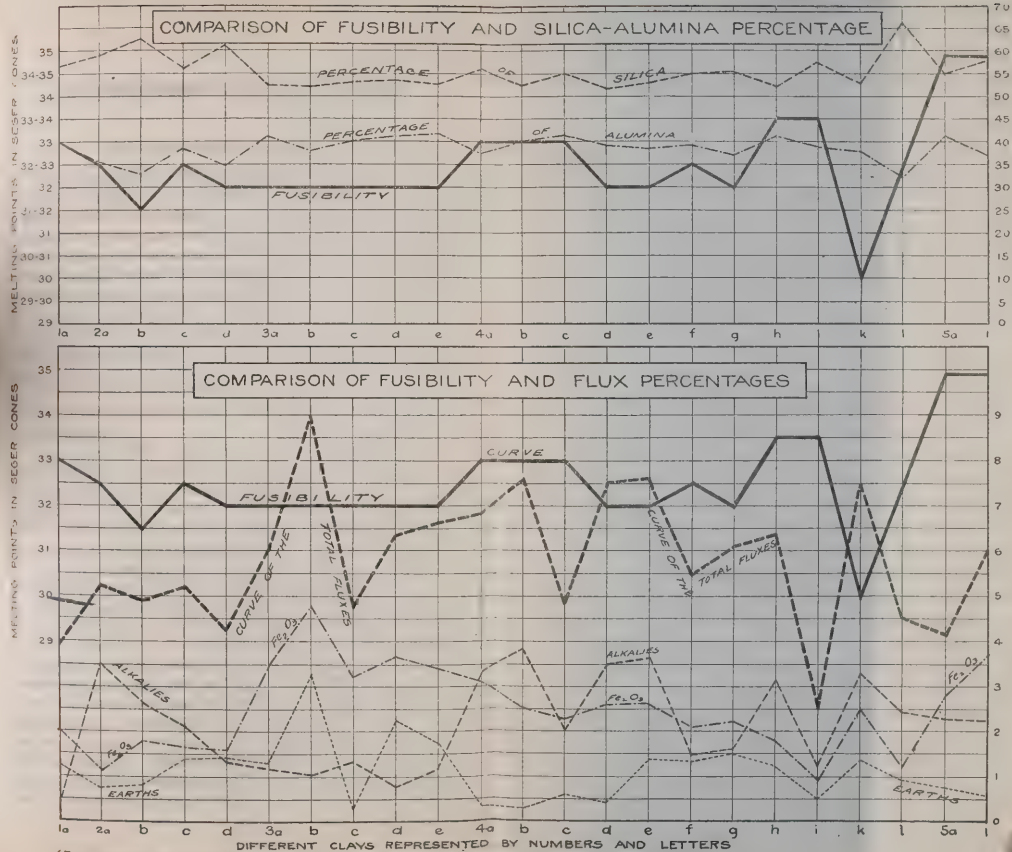
1 Stahl und Eisen, xvi, p. 723; Journ. Iron & Steel Inst., 1897, (1) p. 357.
2 Stahl und Eisen, xxii, pp. 1132-1134.
3 Oesterreichische Zeitschrift fur Berg-u. Huttenwesen, Vol. 1, pp. 492, 494.
4 Tonindustrie-Zeitung, 1903, No. 45, p. 656.

fusion point rises rapidly with increasing content of silica. Still further evidence of the powerful fluxing action of silica may be obtained by glancing along the curve of total fluxes. It will be noticed that Nos. 1 and y are nearly on a level with a; 1, however, contains 8% and y 30% more silica, and as would be expected from what has been shown in the case of American bricks, the fusion point declines from cone 36 to cones 34 and 29 respectively.

With this plate, as with Plate I, the fusibility curve is a steadily descending one, and setting aside the silica bricks, the 55% line, as before, would form a fairly good mean for those clays over cone 30 in fusibility. No mean curve, however, could well be drawn for the sum of fluxes,—which was also found to be the case with the American fire-bricks.

Plate III, taken from Jochum's article in the Tonindustrie-Zeitung, previously mentioned, is comparable only with about the first twenty of the American bricks, both in refractoriness and silica contents. It shows, however, the same variation in the sum of fluxes, and furnishes further evidence that a high flux content does not necessarily indicate a low refractoriness,—which was the conclusion the author reached.

The foreign bricks and clays do not show, in general, such high percentages of total fluxes as do the American, and, as before pointed out, this is due in part to the non-estimation of titanic acid.



(From Tonindustrie Zeitung Vol. 27, 1903, p 771)

AN IMPROVEMENT IN BRICK DRIERS.

BY

W. D. Richardson, Columbus, Ohio.

The improvements of the progressive tunnel brick driers in recent years have been along the line of fireproof construction; longer tunnels; two tracks to a tunnel; tracks either sloping enough to allow the cars, coupled together, to be let down through the drier from the lower end, or tracks nearly level and the cars moved through tunnel by steam or electric power; heated air distributed through tunnels by a large fan and also the saturated air removed from tunnels by a fan instead of by stack; air for drying heated by exhaust steam or from cooling kilns, or both, thus utilizing heat that had previously been allowed to go to waste. These improvements have by no means been universally adopted, nor even frequently all in use in any one dryer, though they are more or less familiar to those who have given attention to these subjects.

A common defect, even in the most modern brick drier, is poor circulation, especially at the receiving end. Here it will be frequently found that hot and only partially saturated air, is escaping over the top of the brick, while the lower part of the drier is cool and dripping with moisture. To remedy this defect some have made the tunnels shorter. In this way they have secured better circulation and drier air at the receiving end of the tunnels, but at the expense of fuel and power. To be sure, it is argued, since the cooling kilns give more heat than is needed, it can as well be wasted by being discharged through the drier as in any other way. But it costs something to move this excess of air, and in many places there is no heat to spare. The most economical and scientific method of overcoming this defective circulation is by artificial exhaustion of the moist air from the receiving end of the drier by fan. In this manner, longer tunnels can be used and a proper and constant velocity of air in the drier maintained. Induced draft in the drier stacks by means of disc fans has been practiced in a few cases, for several years past, but the large centrifugal exhaust fan, located in the same room

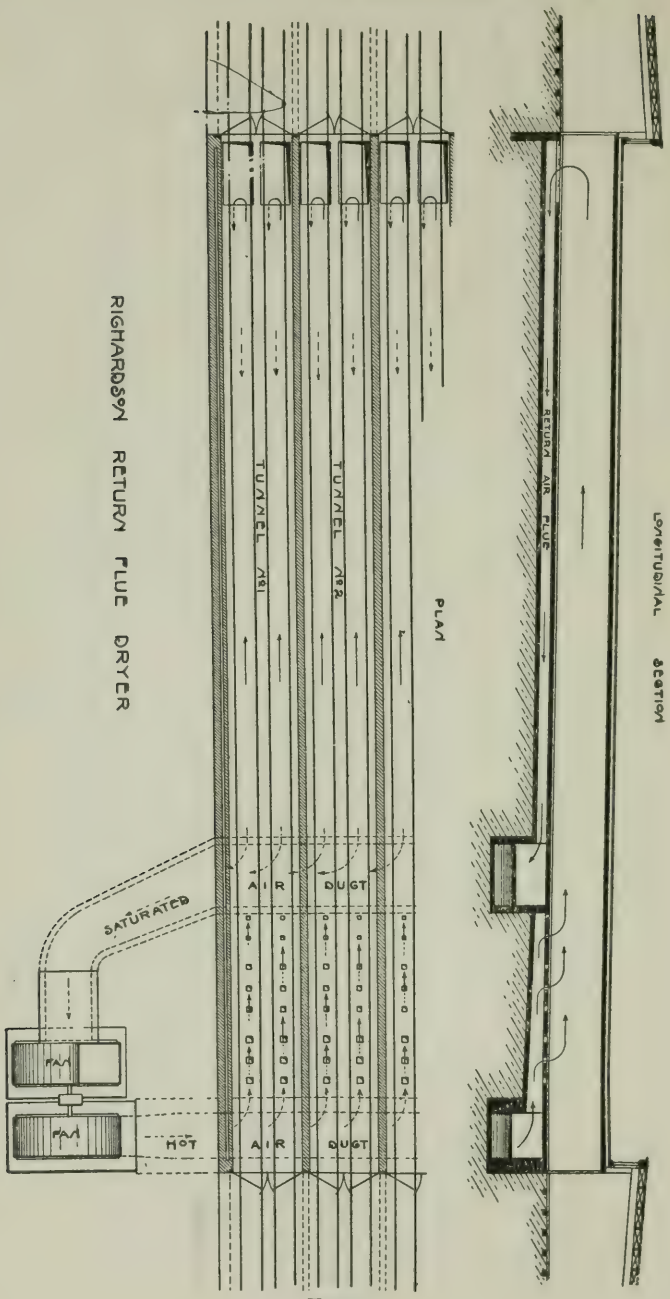

RICHARDSON RETURN FLUE DRYER
PLAN
TUNNEL No1
TUNNEL No2
AIR DUCT
AIR DUCT
SATURATED
HOT
FAN
FAN
LONGITUDINAL SECTION
RETURN AIR FLUE

Fig. 1.

as the forcing fan that blows hot air into the drier, and in some cases connected with it upon the same shaft and driven by the same pulley, has only recently come into use.

These improvements, up to this point, were described in my paper before the Society at the Cleveland meeting. (Transactions Amer. Cer. Soc., Vol. IV.) In the drier of the plant described in that paper, the circulation in drier was maintained by two fans running upon the same shaft. The moist air was pulled out of drier through a transverse flue across the receiving end, and thence conducted through an underground flue, outside of drier, to the fan. This arrangement worked well, but it was observed that the flue, which was covered outside just above the grade level with sawed stone slabs, cemented together, furnishd heat enough on top of the stone for drying sand, as well as for heating dinner buckets, etc. Hence, in the next dryer of this type that I designed, I made use of this heat for warming up the floor of the drier. It is this special feature that is presented in this paper.

The hot air is admitted to drier in usual manner, that is, it is blown into a transverse flue from which it is admitted to flues under each track, and distributed through graduated openings under the cars. The hot air flues under tracks extend only three car lengths, with three opening under each car. At the end of these flues is the wall of the transverse flue that runs across the tunnels for the purpose of collecting the saturated air. This flue has a tight top, but there opens into it on upper side, under each track, a flue that extends to the receiving end of the drier. These flues have a tight top of concrete separating them from the tunnel above, except for a distance of about one car length at the receiving end, where they are open.

These flues under the tunnels not only insure a dry bottom for tunnels, but also help to keep the tunnel floor warm. At the same time, they afford a convenient means of returning the saturated air to the exhaust fan, which is best situated near to the discharge end of drier, in same room with the fan that supplies the hot air. The hot air fan should be placed so as to blow directly into the main transverse flue.

The question whether to have both fans of same size, and on same shaft, driven by one pulley, or to have the exhaust fan a smaller fan, driven by separate pulley, depends upon whether the

forcing fan draws its hot air from a heater close at hand, or from kilns at a distance. In the latter case, this fan must be considerably larger than would be required to exhaust the saturated air from the drier. For scientific adjustment, the fans should be separate, but in practical operations the combined fans have some points in their favor. My experience has been mostly with the latter, and hence this form has been shown on drawing.

This improvement in drier is, I believe, worthy of adoption where the best construction can be afforded. It is a little more expensive in first cost, but the increased efficiency of the drier should amply justify the slightly increased cost. This form is adapted to progressive tunnel driers, where steam or hot air from cooling driers is employed.

AN INVESTIGATION OF THE E. G. ACHESON PROCESS OF TOUGHENING CLAYS.*

BY

LeRoy Hines Minton, E. M. (in Cer.).

Mineral City, Ohio.

On March 17th, 1903, the United States Patent Office issued Patent No. 722,791 to E. G. Acheson, of Niagara Falls, N. Y., covering claims for the production or manufacture of earthenware.

PROCESS AND CLAIMS OF ACHESON.

1st. According to the specifications to the Patent, the process consists in first working the clay into the mixed state, plastic or slip, and then introducing a certain amount (usually one-half to two per cent by weight) of tannin, or any tannin compounds, or any other so-called "modifying agent," such as may be secured from various vegetable compounds, having properties similar to tannin.

The specifications claim that "the plasticity of the clay so treated is much increased, shrinkage in drying is much reduced, while the tensile strength is increased over 40%."

2nd. In a printed article read before the American Ceramic Society at Cincinnati, on February 2nd, 1904, Mr. Acheson sets forth the experiments performed by himself and Dr. Ries, of Cornell University. Briefly the claims made in this article are as follows:

1. Decreased amount of water for tempering.
2. Increased plasticity.
3. Decreased shrinkage.
4. Decreased cracking.
5. Increased density and decreased porosity.
6. Increased tensile strength.
7. Increased hardness.
8. Elimination or reduction in amount of ball clay, or

* A thesis presented for the degree of Engineer of Mines in Ceramics in the Ohio State University, June, 1904.

substitution in whole or in part of kaolin for ball clay in white ware bodies, thus improving the color.

9. Decrease in time necessary for tempering.

Verification of Claims by Others.

The claims made by Mr. Acheson are fully borne out by the experiments made by Dr. Ries. Mr. W. D. Gates, of the American Terra Cotta and Ceramic Company, Chicago, stated in the Convention at Cincinnati that very similar results had been obtained by him by using water glass, or sodium silicate, which he found tended to reduce the amount of water required for slipping by about 40%.

Dr. Allerton S. Cushman, of the Road Material Laboratory, Washington, D. C., also verified the results and claimed that they furnished a very perfect illustration of his colloid theory of plasticity, as explained in his paper and read before the American Ceramic Society, at Cincinnati, February 2nd, 1904.

Limitation by Cost of Process.

Mr. Acheson claims that the process is applicable to all industries, both in regard to execution and cost, and gives as the expense, an additional cost of $1.50 per ton in the white ware industry, and less in the cheaper grades of clay products.

Assuming an additional cost of $1.00 per ton in the cheaper wares, we see at once that such a method is not practicable. The margin between profit and loss in the brick industry, roofing tile industry and most terra cotta work is so small as to prohibit an increase even of fifty cents per ton, which in the brick industry means $2.00 per thousand brick.

It is very doubtful if any important increase in the value of any clay could be obtained at so small a cost as fifty cents per ton, basing an estimate of cost upon Mr. Acheson's statement of a $1.50 per ton of prepared clay.

The following table shows increase in selling price of common ceramic products, assuming an increased expense of fifty cents per ton of clay for treatment:

Industry.	Amount of Clay.	Selling Price of Product Untreated.	Selling Price of Product Treated.	Increase in Selling Price.
Common brick.....	one ton	$2.30	$2.70	22.70%
Face brick.....	one ton	4.93	5.40	10.10%
Fire brick 1.....	one ton	5.03	5.53	9.94%
Fire brick 2.....	one ton	2.66	3.16	18.70%
Sewer pipe 6".....	one ton	14.00	14.50	3.57%
Roofing tile.....	one ton	22.98	23.48	2.13%
White ware.....	one ton	195.00	195.50	0.256%
Decorated w. w.....	one ton	260.00	260.50	0.192%

For art ware the per cent would be still lower, but here it is not necessary to apply such treatment, for the price permits the use of such clays as bring the desired results.

From this table it is evident that at best the process is limited to the white ware industries and possibly high grade refractory products, special fire brick, glass pots, crucibles, gas retorts, etc. But the main field is in pottery.

PROPOSED EXPERIMENTAL WORK.

The object of this work was to conduct a series of experiments to deduce the practical value of this method.

Sources of Tannin.

(a) Gallo-tannic acid.
(b) Catechu.
(c) Sumac leaves.
(d) Oak bark.
(e) Spruce bark.

Gallo-tannic acid and catechu are at once thrown out of consideration on account of cost. Sumac grows only in limited territory and is too uncertain to use.

Oak bark is largely used in tanning. After the tannin is extracted the wood is used as fuel. The first cost of the bark is $15.00 per ton, and it grows scarcer every year and higher in price, and hence is thrown out.

Spruce bark is stripped from logs in immense quantities by paper mills, where it forms the principal fuel supply, and as the production is limited to certain localities the price is prohibitive.

Other Organic Substances Producing the same Effect as Tannin.

In this connection Mr. Acheson mentions specially liquor derived from boiling oat-straw. In addition we might mention the waste liquor from starch factories, sugar mills, breweries, etc. The cheapest and most abundant supply is oat-straw. Straw costs about $6.00 per ton baled, and can be purchased in a much wider latitude than any other material mentioned. For this reason it was chosen for the basis of these experiments.

Main Points to be Determined by Experiments.

1st. Determination of quantitative effect by plastic process.
2nd. Effect of ageing vs. immediate working.
3rd. Effect by slipping, pressing and working at once.
4th. Effect on bodies in which the ball clay is gradually replaced by china clay.
5th. Effect on color of burned product.
And incidentally
6th. (a) Amount of water for tempering.
(b) Hardness in dry state.
(c) Plasticity.

Means of Measuring the Effects Produced.

In order to get comparable results, some uniform method of measuring the properties produced by the treatment had to be used. It was decided to measure the effect of the treatment by means of the tensile strength shown by brickettes formed from the treated clays.

It is a well known fact that the tensile strength method of measuring the comparative qualities of a clay is widely used, yet the results obtained by different operators vary greatly.

As a preliminary to this work, it was thought best to attempt to secure some means of making the test that would insure more uniform results.

The Fairbanks Standard Cement Testing machine is used by this department for making such tests, and often very poor results have been obtained, due to the pinching action exerted by the clips upon the brickettes. In weak clays testing under 100 pounds T. S., the brickette is usually unable to stand the strain,

and breaks at the point of pinch instead of at the point of smallest cross-section. Fluctuation in the T. S. of a series of brickettes from one clay often reach as high as 50% of the average. Efforts have been made to reduce this pinching action by cushioning the brickettes with rubber, felt and card board, but all of these methods proved very troublesome in use, and the results were little better than those obtained before.

To overcome this difficulty a new shaped brickette was made, with wedge-shaped ends, and a clip was also designed to receive it. The sides of the clip were made adjustable so as to produce a bearing upon the brickette all along its faces, instead of concentrating the pressure at a point.

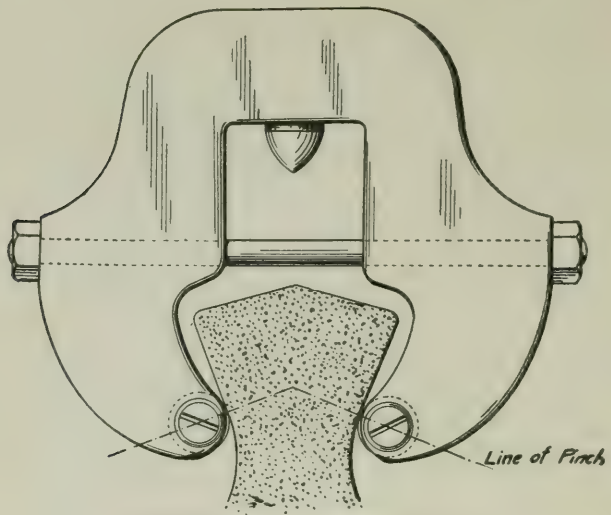
In the illustration on page 236 figure 1 shows the Fairbanks' clip and brickette, while figure 2 shows the clip and brickette designed to replace it.

Testing the Clips.

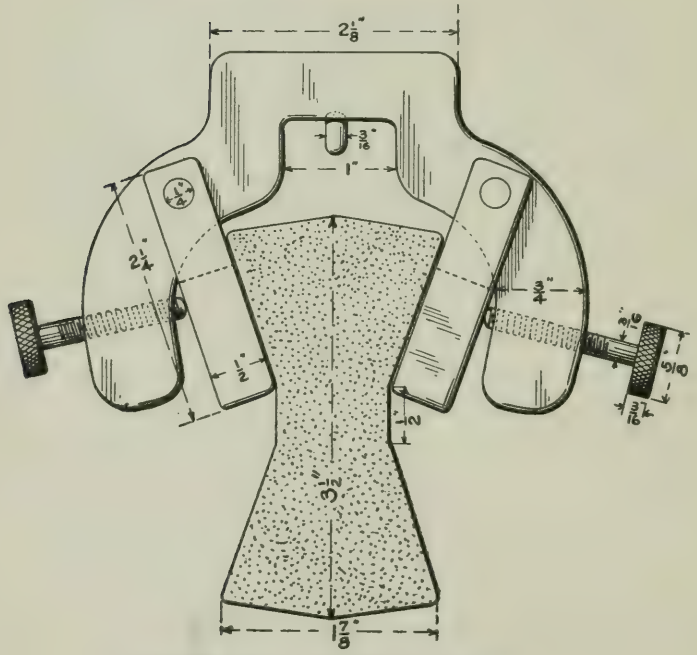
In order to test the relative merits of the clips and brickettes, a number of brickettes were made from each design. The clay used was Haydenville fire clay, run through a 20 mesh sieve, dry. The clay was made up stiff and thoroughly wedged. Great care was used in making these brickettes so as to secure the greatest uniformity. The clay was wedged first in blocks and then out into crumbs of sufficient size to make one brickette. No crumb was used that showed any signs of defect in structure.

The results of pulling the brickettes are given in the table on page 237.

A comparison of the results shows that the percentage of good breaks is much higher under the new conditions, but the fluctuation is not much better, and the tensile strength is much lower. These results can be explained by the manner in which the brickettes were made. The brickettes tested in the old style clips were made in a brass cement brickette mold which was hinged, thus allowing it to open and close around the mass of clay forming the brickette, and insuring a solid mass at the point of smallest cross-section. The mold for the new-shape brickettes was cast from plaster of Paris and the clay had to be pressed into this in forming the brickette. Naturally it was not possible



FAIRBANKS STANDARD CLIP



ADJUSTABLE BRICKETTE CLIP

Fairbank's Clips and Form of Brickettes Used in Cement Testing.				New Style Clips and Brickettes.			
No.	Breaking load	Strength lbs. per sq. in. corrected for area.	Remarks.	No.	Breaking load	Strength lbs. per sq. in. corrected for area.	Remarks.
1	...	.....	Broken in clip	1	58	68.3	Broke square
2	100	113.88	Broke square	2	72	84.8	Broke square
3	79	89.9	Broke very bad	3	78	88.8	Broke square
4	80	94.2	Broke very bad	4	90	102.5	Broke square
5	81	92.25	Broke very bad	5	76	86.5	Broke square
6	95	108.2	Broke very bad	6	78	88.8	Broke square
7	89	98.2	Broke bad	7	74	84.2	Broke square
8	100	110.1	Broke bad	8	76	86.5	Broke square
9	100	68.3	Broke bad	9	85	97.9	Broke square
10	97	110.4	Broke good	10	90	102.5	Broke bad
11	81	92.25	Broke good	11	94	107.0	Broke square
12	98	115.3	Broke bad	12	69	78.6	Broke square
13	94	107.0	Broke good	13	..	.....	Broke in clip
14	91	103.6	Broke good	14	90	106.0	Broke good
15	82	93.4	Broke good	15	70	79.8	Broke very bad
16	92	104.7	Broke good	16	92	108.1	Broke good
17	95	85.4	Broke bad	17	95	104.6	Broke bad
18	83	94.5	Broke good	18	..	.....	Broke in clip
19	69	78.59	Broke bad	19	70	79.8	Broke good
20	99	112.7	Broke good	20	60	68.3	Broke bad
21	95	108.2	Broke good	21	80	91.1	Broke good
22	95	104.7	Broke bad	22	84	95.6	Broke good
23	98	88.8	Broke bad	23	79	89.9	Broke good
24	89	101.36	Broke bad	24	..	.....	Broke in clip
25	88	88.8	Broke bad	25	..	.....	Broke in clip
26	95	104.6	Broke good	26	50	56.9	Broke good
27	89	98.0	Broke good	27	87	99.1	Broke good
28	80	91.11	Broke good	28	106	120.7	Broke good
29	55	63.7	Broke bad	29	80	91.1	Broke good
30	109	120.0	Broke good	30	73	83.1	Broke bad
31	96	105.7	Broke good	31	69	75.9	Broke bad
32	86	97.9	Broke good	32	80	91.1	Broke good
33	56	63.7	Broke bad	33	37	42.1	Broke good
34	93	105.9	Broke bad	34	80	91.1	Broke good
35	109	124.1	Broke good	35	80	91.1	Broke bad
36	89	98.2	Broke good	36	70	79.8	Broke good
37	91	100.2	Broke bad	37	68	77.4	Broke good
38	81	89.2	Broke good	38	60	66.0	Broke good
39	100	113.88	Broke bad	39	70	79.8	Broke good
Maximum 120.0				Maximum 120.7			
Minimum 68.3				Minimum 77.4			
Average 105.5				Average 92.5			
Fluctuation 43.0				Fluctuation 35.8			
11.1% broke very bad				72.9% broke square			
44.4% broke bad				14.2% broke bad			
44.4% broke good				3.9% broke very bad (crushed)			

to form as solid a brickette as where the mold closed around the clay.

In an attempt to overcome this defect two other sets of brickettes were made up, using the cement mold for all. The brickettes that were to be pulled with the new clips were then made to fit them accurately by rounding off the corners, and bringing the faces to a true plane, by sand-papering them smooth.

The following table gives the results obtained from this new set of brickettes:

Old Style Clips.				New Style Clips.			
No.	Breaking load	Strength lbs. per sq. in. corrected for area.	Remarks.	No.	Breaking load-	Strength lbs. per sq. in. corrected for area.	Remarks.
1	..	....	Broke in clip	1	73	83.1	Broke bad
2	80	91.1	Broke good	2	76	89.5	Broke bad
3	77	87.7	Broke good	3	69	81.2	Broke good
4	71	83.1	Broke good	4	69	81.2	Broke good
5	70	77.0	Broke bad	5	72	84.8	Broke good
6	58	63.8	Broke bad	6	70	82.4	Broke good
7	..	....	Broke in clip	7	71	80.8	Broke good
8	66	75.1	Broke bad	8	70	82.4	Broke good
9	89	98.0	Broke bad	9	69	78.5	Broke good
10	69	78.5	Broke bad	10	76	89.5	Broke bad
11	78	88.0	Broke good	11	73	85.9	Broke good
12	65	74.1	Broke bad	12	25	29.4	Flaw
13	70	82.4	Broke bad	13	26	30.6	Flaw
14	..	....	Broke in clip	14	73	83.1	Broke good
15	71	83.1	Broke good	15	72	84.8	Broke good
16	65	74.1	Broke good	16	73	83.1	Broke good
17	72	82.0	Broke good	17	75	85.4	Broke good
18	70	79.7	Broke bad	18	74	87.1	Broke good
19	58	63.8	Broke bad	19	69	78.5	Broke good
20	72	79.2	Broke bad	20	77	90.7	Broke good
				21	77	90.7	Broke good
Maximum 98.0				Maximum 90.7			
Minimum 63.8				Minimum 78.5			
Average 80.1				Average 85.6			
Fluctuation 34.9				Fluctuation 13.4			
Good breaks..... 42.2				Good breaks 84.3			
Bad breaks 58.8				Bad breaks 14.7			

Very much better results were obtained in this way, as all the brickettes were made in the same manner.

The percentage of bad breaks with the new clips is very small, almost no crushing resulting, for the pressure was brought to bear over the entire plane of the face instead of in a line.

This method was used in all of the work. In some cases not so good results were obtained, due probably to the fact that not so much care was taken in trimming the brickettes as in the preliminary tests. But in every case it is believed that much better results were obtained than would have been otherwise possible.

Establishing Quantitative Proportions Between the Clay and the Amount of Straw Required.

In order to reach any conclusions, it was necessary to arrive at some knowledge of the quantitative effect of this treatment. It was thought best to establish the proportions by weight, between the dry straw and the dry clay, avoiding all uncertainties due to the amount of fluid used in tempering.

The extract was prepared by boiling clean oat-straw for two hours in distilled water in a closed vessel. The liquor was then evaporated until a slight scum began to form upon the surface. The evaporation was then stopped, leaving the liquor completely saturated and somewhat syrupy in consistency. The liquor was as dark as Orleans molasses, though not as viscous, and smelled badly.

By weighing the straw and measuring the resultant liquor it was found that 1 c.c. of liquor was equivalent to .266 grams of straw.

The body chosen for this test had the following composition:

Tennessee Ball Clay No. 2	33%
Florida Kaolin	33%
Flint	17%
Spar	17%

800 grams of this body, or enough to make eight brickettes were taken for each series.

Series A.

A portion of the clay was worked into a stiff plastic mass, adding pure distilled water from a burette. 294 c.c. was required It was thoroughly worked up and made into brickettes. This gave some idea as to the maximum amount of straw liquor that would probably be required.

Series B.

The same amount of body was now taken, and straw liquor added until the mass had as near the same consistency as Series A, as could be judged from its working qualities. 274 c.c. liquor was required. The mass was wedged and made into brickettes.

Since 1 c.c. of the liquor contained soluble matter from .266 grams straw, then 264 c.c. liquor was equivalent to 72.884 grams straw, or 182.2 pounds straw per ton of clay, which was the maximum amount used in any test. Other series were then prepared, using less and less straw liquor, and adding pure water to bring the clay up to the same degree of plasticity, as shown in the following table:

Table Showing Amount of Liquor Required for Tempering Clay.

Series	Amount Straw Liquor required in c. c.	Amount Water required c. c.	Total Liquor in c. c.	Pounds Straw Per Ton Clay
A	.....	294.0	294.0	0.0
B	274.0	.....	274.0	182.2
C	225.6	41.6	267.2	150.0
D	187.9	71.7	259.6	125.0
E	150.3	113.2	243.5	100.0
F	112.4	148.8	261.2	75.0
G	75.2	178.0	253.2	50.0

In the discussion of this subject before the American Ceramic Society, the ground was taken that the action of tannin was that of colloids in general, and that other colloids would answer the same purposes that the tannin fills. Soluble glass or sodium silicate was mentioned in that connection, and to test the truth of this view, the following trial was made:

Series H.

Three grs. of sodium silicate was added to 800 grs. clay. The silicate made only 6 c.c., and in addition water to the amount of 155.5 c.c. was required, making a total of 161.5 c.c. liquid.

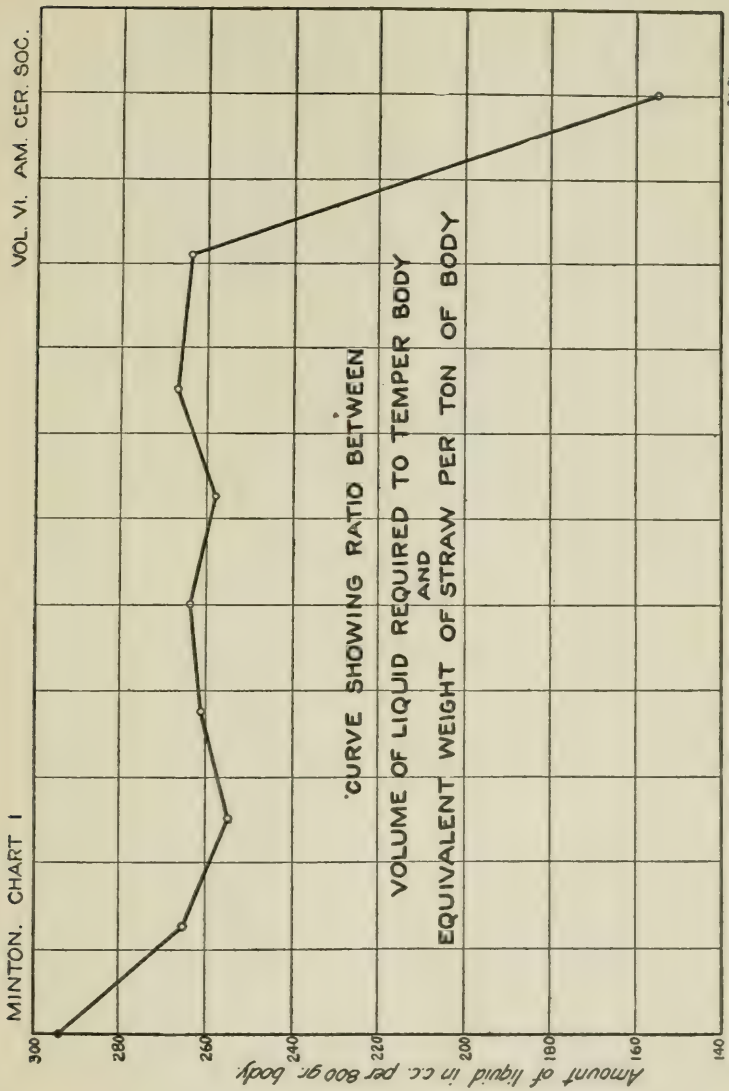
The curve on page 241 shows the amounts of liquor required in each case:

Appearance of Brickettes.

A very decided darkening in color was shown toward that end of the series containing the most straw liquor.

A part of the brickettes became rather too dry before trimming, and while those made up with water alone were easily cut with a spatula, the others were cut only with great difficulty.

All of the brickettes were allowed to dry in the laboratory, and when about leather dry they were trimmed and marked. When thoroughly dry, the brickettes were carefully measured to 32nds inch, the average of the opposite faces taken where any


MINTON. CHART I
VOL. VI. AM. CER. SOC.
CURVE SHOWING RATIO BETWEEN
VOLUME OF LIQUID REQUIRED TO TEMPER BODY
AND
EQUIVALENT WEIGHT OF STRAW PER TON OF BODY
Amount of liquid in c.c. per 800 gr. body
Equivalent weight in pounds of straw per ton of body
% % water abso

difference was found, and were then broken in the testing machine. The following table shows the results:

SERIES A—Water.			
No.	Breaking load	Strength in lbs. per sq. in. corrected for area	Remarks.
1	..	.....	Good break
2	16	18.22	Good break
3	16	18.22	Good break
4	22	24.57	Good break
5	25	27.53	Good break
6	18	21.20	Good break
7	22	24.57	Good break
8	15	17.09	Good break

Maximum 27.53
Minimum 17.04
Average 18.92
Fluctuation 37.80

SERIES B. 182.21 lbs. Straw to 1 Ton Clay.			
No	Breaking load	Strength in lbs. per sq in corrected for area	Remarks.
1	30	33.64	Good break
2	34	40.03	Good break
3	38	41.85	Bad break
4	30	34.16	Good break
5	30	33.64	Good break
6	30	33.64	Good break
7	32	36.44	Good break
8	43	47.35	Good break

Maximum 47.35
Minimum 33.64
Average 37.59
Fluctuation 28.90

SERIES C. 150 lbs. Straw to 1 Ton Clay.			
1	38	43.33	
2	30	35.33	
3	32	36.48	
4	30	35.33	
5	32	36.48	
6	36	41.07	
7	18	21.20	Flaw
8	42	47.83	

Maximum 47.83
Minimum 35.33
Average 39.40
Fluctuation 26.10

SERIES D. 125 lbs. Straw to 1 Ton Clay.			
1	34	37.44	
2	35	39.75	
3	40	45.56	
4	41	45.15	
5	30	35.33	
6	42	46.25	
7	46	54.18	
8	52	57.24	

Maximum 57.24
Minimum 35.33
Average 45.1
Fluctuation 38.2

SERIES E. 100 lbs. Straw to 1 Ton Clay.			
1	47	51.76	
2	43	48.88	
3	45	51.25	
4	..	.....	Broke in clip
5	..	.....	Flaw
6	37	42.16	
7	35	41.22	
8	40	45.56	

Maximum 59.47
Minimum 38.72
Average 48.29
Fluctuation 34.9

SERIES F. 75 lbs. Straw to 1 Ton Clay.			
1	35	38.72	
2	40	45.56	
3	25	27.53	Flaw
4	48	52.86	
5	47	53.53	
6	25	27.53	Flaw
7	36	39.64	
8	54	51.41	

Maximum 59.47
Minimum 38.72
Average 48.29
Fluctuation 34.9

SERIES G. 50 lbs. Straw to 1 Ton Clay.				SERIES H. Sodium Silicate, ⅜ Percent of Dry Weight of Clay, made up into Thin Solution			
No.	Breaking load	Strength in lbs. per sq. in corrected for area.	Remarks.	No.	Breaking Load.	Strength in lbs. per sq. in. corrected for area.	Remarks.
1	35	39.75		1	36	40.91	
2	38	41.85		2	34	37.44	
3	40	45.56		3	40	45.56	
4	30	34.17		4	35	41.22	
5	..	.....	Flaw—broke	5	30	34.17	
6	..	.....	Flaw—broke	6	..	.....	Broke in clip
7	35	38.54		7	30	35.33	
8	40	45.56		8	27	31.80	
Maximum 45.56				Maximum 45.56			
Minimum 34.17				Minimum 31.80			
Average 40.9				Average 38.06			
Fluctuation 25.0				Fluctuation 30.2			

The result of these tests shows that the addition of straw liquor makes a very great improvement in the strength of the body. Seventy-five pounds of straw per ton of body gave the best results. 166% over the strength of the clay molded with water alone. The figures are shown graphically in curve on page 244.

The above results were unexpected in showing the maximum results with so low an amount of straw. In order to verify it, and to test the effects of still lower amounts, the work was repeated using 25, 50, and 75 pounds straw per ton of body—Series F., G. and I. In addition to these two other series were also made:

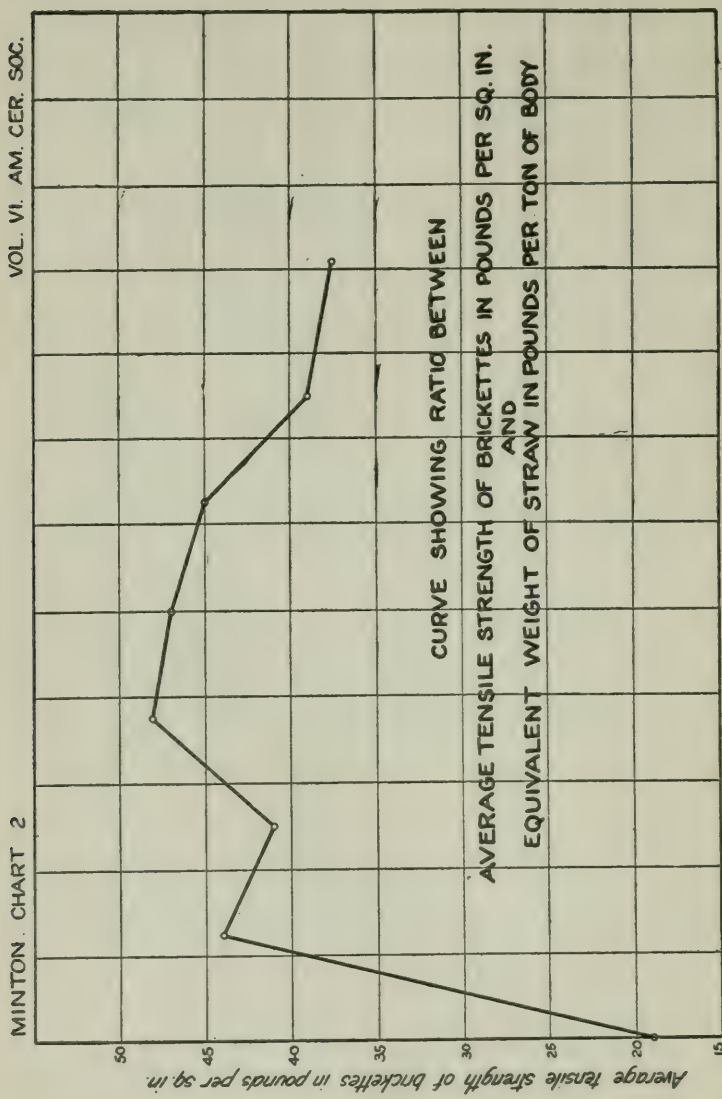
Series O.

800 grs. clay made into brickettes, using as fluid the refuse from a starch factory. This solution was thick, containing 0.2 gr. solid matter per c.c. liquid. 300 c.c. liquid or 60 gs., solid substance was required to be equivalent to 150 pounds per ton body.

Series P.

A thinner solution containing .052 gr. solid per 1 c.c. was used. 300 gr. liquid or 15.6 gr. solid were added to the clay—equivalent to 39 pounds solid substance per ton clay. This was made into brickettes as before.

The results of these five series are shown in the table on page 245.


MINTON. CHART 2
VOL. VI. AM. CER. SOC.
CURVE SHOWING RATIO BETWEEN
AVERAGE TENSILE STRENGTH OF BRICKETTES IN POUNDS PER SQ. IN.
AND
EQUIVALENT WEIGHT OF STRAW IN POUNDS PER TON OF BODY
Average tensile strength of brickettes in pounds per sq. in.
Equivalent weights of straw in pounds per ton of body
50
45
40
35
30
25
20
15
0
20
40
60
80
100
120
140
160
180
200

DUPLICATE SERIES F.
75 lbs. Straw per 1 Ton Clay.

No.	Breaking load	Strength in lbs. per sq. in corrected for area.	Remarks.
1	41	46.7	
2	..	....	Broke in clip
3	44	50.1	
4	22	....	Flaw
5	41	46.7	
6	37	42.1	
7	..	....	Broke in clip
8	44	50.1	

Maximum 50.1
Minimum 42.1
Average 47.1
Fluctuation 16.0

DUPLICATE SERIES G.
50 lbs. Straw per 1 Ton Clay.

No.	Breaking load	Strength in lbs. per sq. in. corrected for area.	Remarks.
1	42	47.8	
2	36	42.4	
3	40	45.5	
4	37	43.5	
5	27	....	Flaw
6	40	45.5	
7	35	39.8	
8	37	43.5	

Maximum 47.8
Minimum 39.8
Average 44.0
Fluctuation 16.7

SERIES I.
25 lbs. Straw per 1 Ton Clay.

1	35	39.7	
2	32	37.6	
3	40	45.5	
4	35	41.2	
5	46	52.4	
6	36	41.0	
7	37	42.1	
8	45	51.1	

Maximum 52.4
Minimum 37.6
Average 43.8
Fluctuation 28.2

SERIES O.
Using Heavy Starch Solution.

1	27	30.7	
2	30	34.1	
3	20	22.7	Flaw
4	30	34.1	
5	15	17.0	Flaw
6	30	34.1	
7	35	39.8	
8	37	42.2	

Maximum 42.2
Minimum 30.7
Average 35.8
Fluctuation 27.2

SERIES P.
Using Thin Starch Solution.

1	40	45.5	
2	..	....	Broke in clip
3	32	36.4	
4	..	....	Broke in clip
5	39	44.4	
6	33	37.5	
7	34	38.7	
8	40	45.5	

Maximum 45.5
Minimum 36.4
Average 41.3
Fluctuation 20.0

The results of these series verify series F and G very closely. They also show that by using the starch solution almost as good results can be obtained as by using straw.

Consideration of Cost.

Having established the relation between the quantity of straw and its effect under the preceding conditions, it now becomes possible to discuss the question of cost and whether the process is practical from a financial standpoint.

A great deal of difficulty was found in connecting the cost of the body with the cost of the ware. Almost the only literature found on this subject were two articles by Mr. Ernest Mayer, published in the Transactions of the American Ceramic Society, Vol. II, p. 160 and Vol. III, p. 193. From these articles, we find that 40,000 complete sets of assorted table ware cost $143,352.00. There was a total loss of 2%, due to breakage, cracking, etc. The biscuit loss alone was 1.18%.

As a basis, we assume that by using straw solution we cut down the loss to 1½%, or make a saving of 0.5%. It must be stated here, however, that a saving of 0.5% is a very liberal assumption, when we consider all of the causes to which the 2% total loss may be assigned; 0.5% is about 50% of the total biscuit loss and 25% of the total loss from all causes.

From the 40,000 sets made, 98% or 39,200 sets are salable. Those 39,200 sets were made at a total cost of $143,352, or $3.659 per set.

If, by treating the clay with this method, we can, according to the above assumption, produce 98.5% or 39,400 salable sets, we cut the cost down from $3.659 to $3.638 per set, or a saving in cost of 2.1 cents per set. This saving of 2.1 cents per set in cost means a total saving of $827.40 in the cost of making 39,400 sets.

It is a fair proposition then that this $827.40 can be spent in giving the clay this treatment, if it increases the good sets from 98% to 98.5%, or with not extra total cost turns out 200 extra sets upon which is secured a profit.

Now to produce these 40,000 sets there was required

Flint	440 tons
Spar	175 tons
China Clay	410 tons
Ball Clay	205 tons
Total	1230 tons body.

By the saving of 0.5% ware, we are enabled to spend $827.40 for the treatment of this 1230 tons body, or 67.2 cents per ton.

We may assume that the average plant consumes five tons of clay per day. According to the results found, 75 pounds straw per ton of clay gives the maximum results; then five tons of clay require 375 pounds or 0.1875 ton straw, which is to be handled every day. One ton of clay requires approximately one ton of water to slip it. To slip five tons of clay per day requires five tons of straw liquor. In order to handle this amount, or 320 cubic feet, there would be necessary some kind of boiler, or vat, such as is used in the tanneries.

At a small cost, a vat of sufficient size could be constructed, provided with a heavy grating or iron frame, raised and lowered by pulleys to hold the straw under the surface of the water.

The liquid could be heated with exhaust steam. After the straw had been used for making the infusion, it would not be feasible to dry it and use it for packing, because the heat and apparatus for artificial drying, or the time, labor and annoyance in natural drying, would amount to more than the first cost of the straw.

It is evident, then, that the first cost of apparatus for putting this treatment into operation is small, and probably not greater than the expense necessary in ageing the clay.

The labor required in putting 375 pounds of straw into the vat and removing it would hardly be more than two hours work for one laborer.

The running expense of this treatment per day, or for five tons of body, would be

375 lbs. straw at $6.00 per ton.....	$1.125
2 hours work at 12½ cents per hour...	0.25
Total	$1.375

or $0.275 per ton clay treated.

We have shown before that if by this treatment we can cut down the loss by 0.5%, a saving of $827.40 is made in making 39,400 sets of white ware. To make this requires 1230 tons of clay, which costs $0.2750 per ton for treating. This means an expense of $338.25 in making 39,400 sets. Thus the treatment makes a saving of $827.40—338.25=$489.15 in the cost, to which must be added the profit on the 0.5% or 200 sets of salable ware saved from going out as scrap.

It follows from this reasoning, that the process is a feasible one from a financial standpoint, provided it produces the desired results, or bears out the above assumption. It must be remembered, however, that the plant from which these figures were taken is run upon a very high scale of development, and therefore while a small saving of $500 per year is made, it is not favorable to Mr. Acheson's point of view, in that it does not represent the average commercial conditions.

In order, therefore, to present the case as fairly as possible to Mr. Acheson, we will take a purely hypothetical case which we believe nearer the conditions upon which Mr. Acheson would base the value of his method.

Let us suppose that in a plant making 40,000 dinner sets per year, the total loss is equal to 10%, of which 6% is biscuit loss, not including the loss in making and drying, which falls upon the operative potters.

As a basis we may assume that 50% of the biscuit loss is prevented by this treatment, or, the total loss is cut down from 10% to 7%.

The cost of making 40,000 sets is $143,352. If the total loss is 10%, then 90%, or 36,000 sets are salable. The cost per set is then 143,352÷36,000=$3.982. If the loss is cut down to 7% then 93% or 37,200 sets are salable. The total cost of production is $143,352, hence each set costs $3.853. This is a saving of $3.982—3.853=$0.129 per set, or 4798.80 in the total of 37,200 sets.

We found before that the cost of the treatment was $338.25. This makes a net saving of 4798.80—338.25=$4460.55, plus the profit on 1,200 sets of ware.

The saving in this case is great enough to bear consideration. But it must be remembered that these results are based entirely upon hypothesis. The value of these calculations depends entirely upon the condition that the treatment itself bears out the hypothesis, or that it will produce a saving of 50% of the biscuit loss under the given conditions, and the results of the experiments so far conducted do not allow the statement that such benefits will follow this treatment.

Effect of Aging.

In order to determine whether the process takes the place of aging, or whether clays treated by the Acheson process would show a still further gain in tensile strength after aging, two series were made and allowed to stand for eighteen days before making into brickettes.

Series N.

Using strongest straw solution or 182.2 pounds straw per ton body.

Series M.

Using water alone for tempering.

The results of the tensile tests are as follows:

SERIES M. Using Pure Water—Aged 18 Days.			SERIES N. Using 182.2 lbs. Straw per Ton Clay		
No.	Breaking load	Strength in lbs. per sq in corrected for area.	No.	Breaking load	Strength in lbs. per sq. in. corrected for area.
1	40	48.7	1	50	56.9
2	35	41.2	2	52	57.2
3	36	43.9	3	51	56.1
4	37	43.5	4	51	56.1
5	40	48.7	5	55	56.5
6	41	47.5	6	55	60.5
7	42	49.4	7	51	56.1
8	38	44.7	8	46	52.4
9	44	51.8			
Maximum 51.8			Maximum 60.5		
Minimum 41.2			Minimum 52.4		
Average 46.6			Average 57.2		
Fluctuation 20.4			Fluctuation 13.3		

The results from aging the clay shows a very marked improvement over those from the clays that were not aged, especially in the case where water alone is used. By aging we secure an increase in tensile strength of from 18.92 pounds to 46.6 pounds where water alone is used for tempering, and where the straw solution is used the increase is from 37.5 to 57.2 pounds.

While the gain in aging is not as great as when water is used alone, still it is considerable. It really is an argument in favor of the Acheson process, in that it shows that the latter exerts its action almost immediately and renders aging unnecessary.

The results have shown that it is not necessary to use large proportions of straw in order to secure the maximum results, hence 75 lbs. straw per ton of clay was selected as the basis for further work.

The Effect of Slipping on the Strength of the Clay.

The foregoing tests have been made on clay tempered with the minimum quantity of water to make it up to a plastic paste. Under these conditions certain benefits have been shown to accrue from the use of straw solution instead of water. But in making white ware bodies we must expect to slip the clays thoroughly, in order to incorporate the flint, spar, etc., into the mixture with perfect homogeneity. Instead of 25% of water as in the plastic process, about 100% is needed for slipping, and the straw solution is thus rendered correspondingly dilute.

To determine whether this dilution affects the resultant action on the clay, the following tests were made.

Five series were made, in each case the clay being slipped to as nearly a uniform density as possible, thoroughly blended and allowed to stand twelve hours. The slip was then filter pressed to just the density for working well, and made into brickettes.

The results of the tensile tests were as given in tables on page 251.

These tests show the surprising fact that when the clay is slipped the strength secured by using water alone is as great as by using the different solutions tested. With water alone we secure an increase of from 18.92 lbs., by stiff-mud method, to 53 pounds slip method, while with straw solution the increase is from 48.3 to 51.2 pounds, the latter being less than with water alone.

The curve on page 252 shows the difference in working the clay into brickettes, stiff-mud and slip process:

Substitution of China Clay for Ball Clay.

The object here was to secure greater whiteness in the body by using china clay for ball clay, while still attempting to preserve the plasticity of the body by the Acheson treatment, this being one of the chief advantages claimed under his method.

The body chosen for the experiments was designed to mature a good white ware body at cone 4. The formula was:

$$\left.\begin{matrix}0.12\ CaO\\0.18\ K_2O\end{matrix}\right\}\ 1.\ Al_2O_3,\ 4.38\ SiO_2$$

SERIES I.
75 lbs. Straw per 1 Ton Clay.

No.	Breaking load	Strength in lbs. per sq. in. corrected for area.	Remarks.
1	50	58.8	
2	42	47.8	
3	47	56.5	
4	46	54.0	
5	42	47.8	
6	40	45.5	
7	43	48.9	
8	..	....	Broke in clip

Maximum 58.8
Minimum 45.5
Average 51.2
Fluctuation 22.6

SERIES II.
50 lbs. Straw per 1 Ton Clay.

No.	Breaking load	Strength in lbs. per sq. in. corrected for area.	Remarks.
1	45	49.5	
2	42	47.8	
3	48	54.6	
4	37	43.5	
5	42	47.8	
6	..	....	Broke
7	40	44.0	
8	40	44.0	

Maximum 54.6
Minimum 43.5
Average 47.3
Fluctuation 20.3

SERIES III.
Using Heavy Starch Solution 150 Lbs. Solids per 1 Ton Clay.

1	42	47.8	
2	50	58.8	
3	55	60.5	
4	45	51.2	
5	48	52.8	
6	47	56.5	
7	42	47.8	
8	50	56.9	

Maximum 60.5
Minimum 47.8
Average 54.0
Fluctuation 21.0

SERIES IV.
Thin Starch Solution 39 lbs. Solids per 1 Ton Clay.

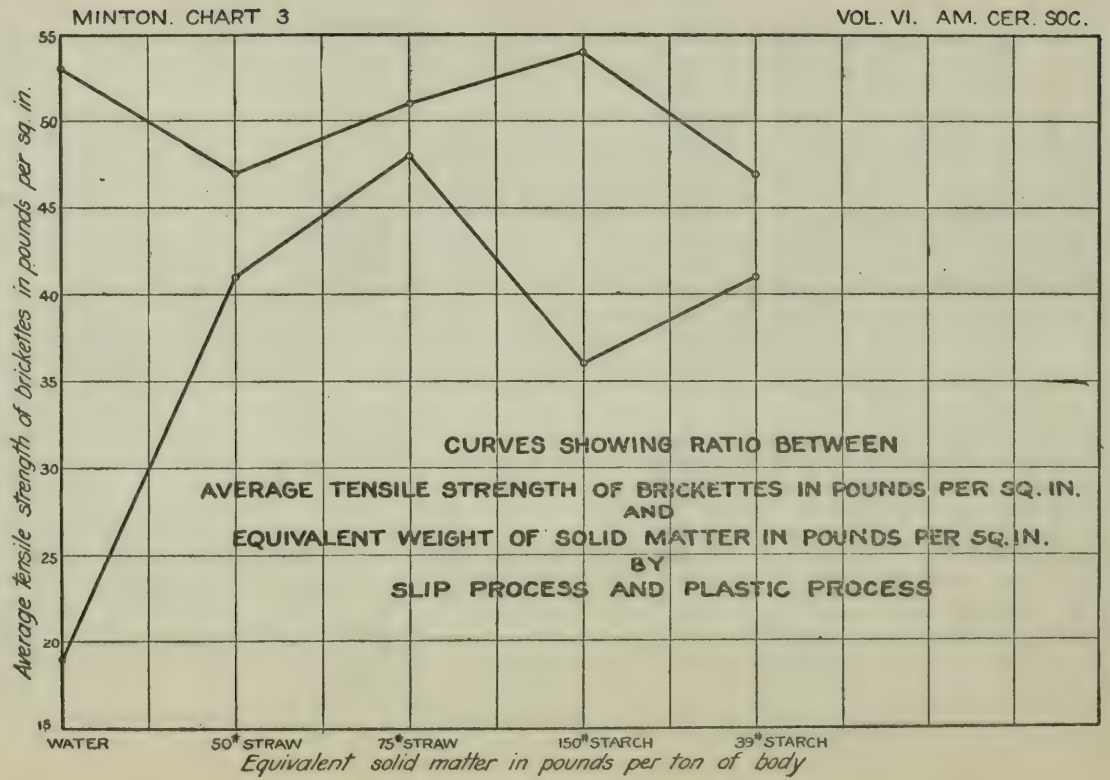
1	42	47.8	
2	40	45.5	
3	42	49.4	
4	40	45.5	
5	38	44.7	
6	..	....	
7	42	49.4	
8	40	47.1	

Maximum 49.4
Minimum 44.7
Average 47.0
Fluctuation 9.5

SERIES V.
Using Water Alone.

1	44	52.0	
2	50	56.9	
3	42	47.8	
4	45	53.0	
5	52	59.1	
6	45	53.0	
7	40	47.1	
8	47	55.6	

Maximum 56.9
Minimum 47.1
Average 53.0
Fluctuation 17.2


MINTON. CHART 3
VOL. VI. AM. CER. SOC.
Average tensile strength of brickettes in pounds per sq. in.
55
50
45
40
35
30
25
20
15
CURVES SHOWING RATIO BETWEEN
AVERAGE TENSILE STRENGTH OF BRICKETTES IN POUNDS PER SQ. IN.
AND
EQUIVALENT WEIGHT OF SOLID MATTER IN POUNDS PER SQ. IN.
BY
SLIP PROCESS AND PLASTIC PROCESS
WATER
50# STRAW
75# STRAW
150# STARCH
39# STARCH
Equivalent solid matter in pounds per ton of body

It was made from English ball clay, English china clay, flint and spar. It will be found on calculation that the clay substance is equal to 50%.

The following bodies, each having the above formula, but varying the clays used, were made by slipping with water and pressing after standing for ten hours:

	Ball Clay	China Clay
Series VI	50	0
Series VII	40	10
Series VIII	30	20
Series IX	20	30
Series X	40	40
Series XI	0	50

Series XII to XVII were similar in composition, but contained in addition straw liquor equivalent to 75 pounds per ton body.

All were made into brickettes as soon as pressed. Not a very great difference was noticed in the working qualities of analagous members of the two series, but considerable difference was found between the extremes of either series by itself.

A very decided color range was shown in each series, and as a whole the series VI, VII, VIII, etc., was much lighter than the XII, XIII, XIV, etc.

The results of the tensile strength are shown in the tables on page 254 and 255.

The results from this set of experiments being condensed in the curves on page 256 show that the influence of the straw solution is very much greater in the bodies in which the ball clay forms the largest per cent. and as the China clay increases, the difference between the two series becomes smaller, until where the largest amounts of China clay are used the difference it not of practical importance.

It is just here that the increase in strength should be expected according to Mr. Acheson's claims. It would seem from this that the treatment really does not in itself create plasticity or strength, but simply acts as a sort of catalytic reagent in developing a "latent" plasticity and strength in an already plastic ball clay, while affecting a kaolin very much less.

WITHOUT STRAW LIQUOR.

SERIES VI.
50 Per cent Ball Clay.

No.	Breaking load	Strength in lbs. per sq in. corrected for area.	Remarks.
1	22	25.0	
2	16	18.2	
3	25	28.4	
4	30	34.2	
5	..	....	Broke
6	20	23.5	
7	16	20.2	
8	15	17.6	

Maximum 34.2
Minimum 17.6
Average 23.8
Fluctuation 48.5

SERIES VII.
40% Ball Clay—10% China Clay.

No.	Breaking load	Strength in lbs. per sq. in. corrected for area	Remarks.
1	13	15.3	Flaw
2	21	24.7	
3	27	30.7	
4	27	30.7	
5	18	20.5	
6	18	20.5	
7	22	25.0	
8	20	22.8	

Maximum 30.7
Minimum 20.5
Average 24.9
Fluctuation 33.2

SERIES VIII.
30% Ball Clay—20% China Clay.

1	15	17.0	
2	18	21.2	
3	16	19.5	
4	16	18.2	
5	20	22.0	
6	19	24.1	
7	19	20.5	
8	17	20.0	

Maximum 24.1
Minimum 17.0
Average 20.3
Fluctuation 29.5

SERIES IX.
20% Ball Clay—30% China Clay.

1	16	19.5	
2	16	18.8	
3	..	....	Broke in clip
4	..	....	Broke in clip
5	10	12.2	
6	12	14.6	
7	12	14.6	
8	14	16.4	

Maximum 19.5
Minimum 14.6
Average 16.0
Fluctuation 25.1

SERIES X.
10% Ball Clay—40% China Clay.

1	10	11.3	
2	11	11.0	
3	11	12.9	
4	12	14.1	
5	12	14.1	
6	11	12.5	
7	11	12.5	
8	10	12.2	

Maximum 14.1
Minimum 11.0
Average 12.5
Fluctuation 21.9

SERIES XI.
50% China Clay.

1	..	....	Broke in clip
2	7	7.9	
3	..	....	Broke in clip
4	..	....	Broke in clip
5	6	6.8	
6	7	7.2	
7	5	5.6	
8	4	4.4	

Maximum 7.9
Minimum 4.4
Average 6.4
Fluctuation 44.3

WITH STRAW-LIQUOR EQUIVALENT TO 75 POUNDS PER 1 TON CLAY.

SERIES XII.
50% Ball Clay.

No	Breaking load	Strength in lbs. per sq in. corrected for area.	Remarks.
1	32	36.4	
2	23	28.0	
3	20	22.0	Flaw
4	33	37.5	
5	24	28.2	
6	27	31.7	
7	30	34.1	
8	30	33.0	

Maximum 37.5
Minimum 28.0
Average 32.7
Fluctuation 25.3

SERIES XIII.
40% Ball Clay—10% China Clay.

No.	Breaking load	Strength in lbs. per sq. in. corrected for area.	Remarks.
1	32	36.4	
2	23	28.0	
3	20	22.0	Flaw
4	33	37.5	
5	24	28.2	
6	27	31.7	
7	30	34.1	
8	30	33.0	

Maximum 37.5
Minimum 28.0
Average 32.7
Fluctuation 25.3

SERIES XIV.
30% Ball Clay—20% China Clay.

1	34	37.4	
2	40	42.6	
3	30	33.0	
4	32	34.1	
5	30	33.0	
6	33	35.1	
7	33	36.3	
8	33	37.5	

Maximum 42.6
Minimum 33.0
Average 36.1
Fluctuation 22.5

SERIES XV.
20% Ball Clay—30% China Clay.

1	19	21.6	
2	21	23.9	
3	24	26.4	
4	19	21.6	
5	25	26.5	
6	23	26.2	
7	24	27.3	
8	19	20.9	

Maximum 27.3
Minimum 20.9
Average 24.3
Fluctuation 23.2

SERIES XVI.
10% Ball Clay—40% China Clay.

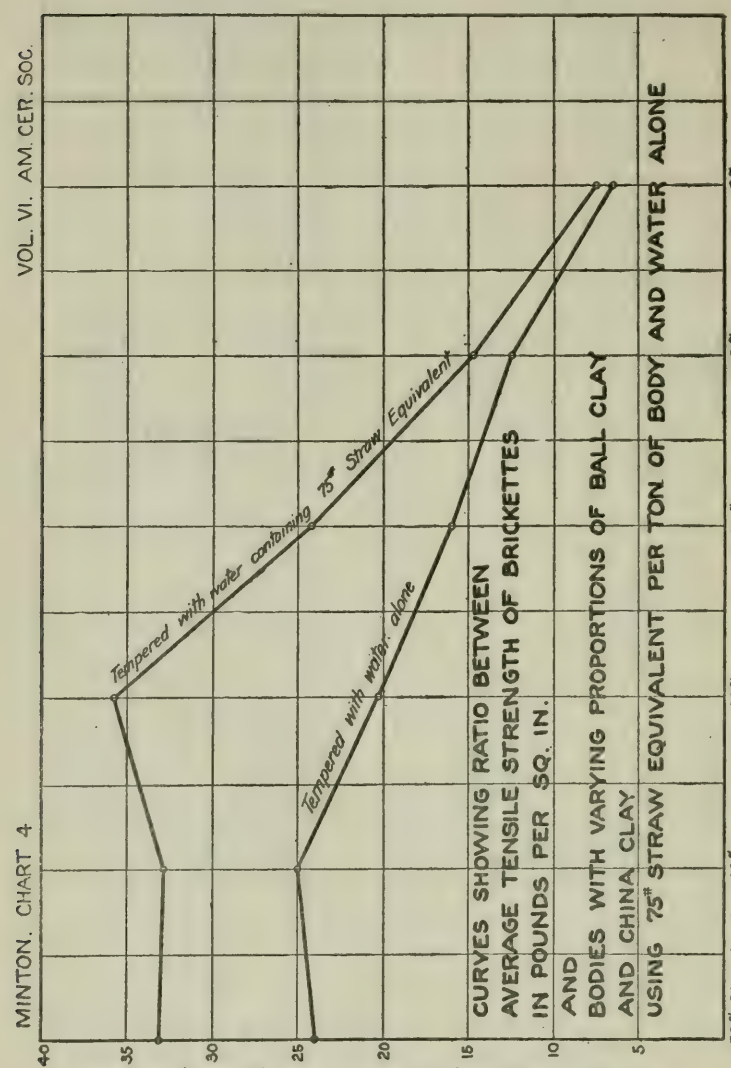
1	14	16.4	
2	16	17.6	
3	14	15.4	
4	11	12.1	
5	9	10.6	
6	13	15.3	
7	13	14.9	
8	13	15.4	

Maximum 17.6
Minimum 10.6
Average 14.7
Fluctuation 39.7

SERIES XVII.
50% China Clay.

1	7	8.2	
2	..	....	
3	8	8.8	
4	6	6.6	
5	7	7.8	
6	6	6.8	
7	7	7.8	
8	7	7.7	

Maximum 8.8
Minimum 6.6
Average 7.6
Fluctuation 25.0


MINTON. CHART 4
VOL. VI. AM. CER. SOC.
CURVES SHOWING RATIO BETWEEN
AVERAGE TENSILE STRENGTH OF BRICKETTES
IN POUNDS PER SQ. IN.
AND
BODIES WITH VARYING PROPORTIONS OF BALL CLAY
AND CHINA CLAY
USING 75# STRAW EQUIVALENT PER TON OF BODY AND WATER ALONE
Tempered with water containing 75# Straw Equivalent
Tempered with water alone
Average tensile strength of brickettes in pounds per sq. in.
40
35
30
25
20
15
10
5
60% BALL CLAY
0 " CHINA
40%
10.
30%
20.
20%
30.
10%
40.
0%
50.
Proportions of ball clay and china clay in body

Burning.

Brickettes from each of the preceding series, VI to XVII, were burned in a saggar in an updraft test kiln to cone 4, requiring ten hours. Very little difference in color is shown between the two series; if anything, the series in which the straw liquor was used is the whiter. Also, very little difference in whiteness is shown between the extremes of each series. It hardly appears that the gain in whiteness is sufficient to justify the use of china clay in place of ball clay.

Influence of Treatment on Glazes.

About the time these experiments were completed other experiments were being made upon stoneware glazes, and great difficulty from crawling of the glaze was experienced. To see what effect the straw liquor might have upon the glaze, a few trials were made, to which the liquor was added.

The glaze had the following composition:

$$\left.\begin{matrix} 0.35\ K_2O \\ 0.32\ CaO \\ 0.32\ ZnO \end{matrix}\right\}\ 0.5\ Al_2O_3\ \ 2.75\ SiO_2$$

To portions of the glaze were added liquor in equivalent amounts of straw to form,

No. 1—0.5% straw to dry weight glaze
No. 2—1.0% straw to dry weight glaze
No. 3—2.0% straw to dry weight glaze
No. 4—3.0% straw to dry weight glaze

These were burned to cone 6 in a quick fire. All the glazes lay much better than those which had not been treated, and the results improved with the amount. In No. 4 almost no crawling resulted. The glazes were of a darker color than the others, due to the fact that the burn was too rapid to allow of oxidation. In all probability the carbon would burn out, if the burning were properly conducted. There would seem some possible room for the use of this method in stoneware glazes, by using china clay in place of ball clay, producing a whiter glaze.

DEDUCTIONS AND CONCLUSIONS.

From the results of these experiments, we may deduce the following points:

1*st*. The maximum results are obtained by using a comparatively small equivalent of straw to clay.

(a) The effects are produced practically at once.

(b) Where the clays are aged before use, the advantage of the process is much curtailed.

(c) Where the body is prepared by the slip method, as is customary in nearly all white ware plants, the advantage of the process becomes so small as to be valueless.

2*nd*. More advantage is gained in bodies that contain considerable ball clay than where china clay is used. The influence is not very marked in the latter case.

3*rd*. The color of the finished product is not materially affected by the application of the process. It may be that the whiteness is slightly increased.

4*th*. Physical effects.

(a) Amount of water needed for tempering is somewhat lessened.

(b) Hardness in dry state is greatly increased, but shows no increase in burned product.

(c) Treatment does not seem to influence plasticity to any marked extent.

As these experiments are very largely confined to determination of the strength of the clay as shown by the tensile test, and as this method of estimating the working properties of a clay is by no means fully accredited, and in fact is considered in some quarters of being of little direct value, it would therefore be rash to reach any broad or sweeping conclusions on this evidence alone. But that it has *some* value can scarcely be doubted, and it is proper, therefore, in the absence of other data, to reach some provisional conclusions.

We have shown that from a financial standpoint the method is restricted to the higher grades of the ceramic industry, or to those classes in which the cost of the raw material is very small as compared with the value of the final product.

In the better classes of ware the method is feasible so far as cost is concerned, provided the desired improvement in quality can be obtained.

The results obtained here are greatly at variance with those obtained by Mr. Acheson. While a great improvement in strength and hardness is found where the treatment is applied to the plastic working of the clays, as soon as the practical method, or that of slipping, is used the advantage dwindles away to nothing.

The best results seem to be gained where clays are used that in a good degree possess the qualities sought, rather than developing the qualities in a clay which does not possess them to any extent. These results are in direct opposition to those of Mr. Acheson, who found a great increase in strength, plasticity and hardness in kaolins and in china clays, that before exhibited these properties in only a small degree.

In the white ware industry it is perfectly possible, with a knowledge of the various clays at command, to obtain the properties demanded in practice, so that it does not appear that this method of treating bodies will be likely to lead to any great economic changes.

The results appear most favorable to industries manufacturing their ware by the plastic process. Here a marked development of properties is produced in a very short time. But as we have shown, the method would be limited to a very few industries because of the cost.

Possibly the process could be applied with profit to the manufacture of high grade fire brick, glass pots, crucibles, gas retorts, etc., but the experiments made do not justify definite conclusions, and further work would be necessary along any special line to be considered.

A TABLE FOR QUICKLY OBTAINING THE SILICA CONTENT OF GLAZES, WHERE THE TOTAL OXYGEN-RATIO AND THE ALUMINA ARE GIVEN.

BY

Ross C. Purdy, Columbus, Ohio.

The accompanying table was made originally by the writer as an aid in designing experiments in glazes for class and research work, and as a rapid means of checking calculations. The idea that it may, in a similar way, be of assistance to others in the calculation of the formulae of ceramic compounds in which the oxygen ratio is used as a basis, and RO unity, was a natural outcome of the original conception.

The table has been enlarged considerably over that of the original so as to include a large range of formulae, with correspondingly wide range in the alumina content as well as in the oxygen ratios themselves.

The distribution of oxygen among the bases, as shown in the two right hand columns, was proposed by Prof. Edward Orton, Jr., to take the place of the inadequate and unconformable "molecular ratio of alumina to silica," which was used by him in some of his earlier work. (See Fickes, Trans. A. C. S., Vol. III, p. 82). Both methods show the amount of alumina present, and compare this with the other glaze ingredients, but, inasmuch as we classify the glaze by the ratio of its total oxygen in base to its total oxygen in acids, it seems more consistent to classify the distribution of oxygen in the bases, i. e., between RO and alumina, in the same manner. In the old method, we used one ratio in discussing one group of facts and a totally different basis for comparison in another set of facts.

The table is calculated on the basis that

$$\text{O. R.} = \frac{2 \text{ times Eqv. } SiO_2}{(3 \text{ times Eqv. } Al_2O_3) + 1}$$

In this expression the total RO oxygen is one, and is represented by the numeral 1.

For any given equivalent of Al_2O_3, the corresponding equivalent of SiO_2 for any oxygen ratio can be found by reading to the right on line with the given Al_2O_3. In a similar manner, the oxygen ratio of a combination of RO, Al_2O_3 and SiO_2 can be determined by reading to the right on line with the equivalent Al_2O_3 corresponding to that in the problem until the corresponding equivalent SiO_2 is found. The O. R. of the combination is then read from top of the column in which the amount of SiO_2 was found. It is likely that the exact figures in the problem can not be found on the table, but they will be close enough for most purposes. For more exact calculations, interpolations can easily be made. This, however, does not hold true in the calculation of the distribution of oxygen in bases, for those figures do not differ by a constant factor as do those in the other columns.

ILLUSTRATIONS.

Problem 1—Required to compound a glaze whose oxygen ratio is 2.25 and whose alumina equivalent is 0.22.

On consulting table, we find in the left hand column, alumina 0.22. Following the top line of the table across to the right, seven columns, we come to the oxygen ratio 1:2.25. At the intersection of these horizontal and vertical columns, we find Silica 1.8675. Our formula is therefore

$$RO,\ 0.22\ Al_2O_3,\ 1.8675\ SiO_2$$

Problem 2—Given a glaze whose formula is

$$\left.\begin{matrix} 0.22\ KNaO \\ 0.06\ BaO \\ 0.18\ CaO \\ 0.52\ PbO \\ 0.02\ CoO \end{matrix}\right\} 0.287\ Al_2O_3,\ 3.21\ SiO_2$$

What are its oxygen ratios?

No matter how complex it may be, the RO flux is always 1 in total oxygen. This is the fundamental assumption in the case. Looking again in the left hand column, under Al_2O_3, we find 0.285 the nearest Al_2O_3 value given. Following across to the right, we find 3.24 the nearest silica value given. Following up this line, we find the oxygen ratio is 1:3.5. Our answer would be, therefore, 1:3.5 nearly, and subdividing the basic oxygen,

Equivalent of Alumina	Oxygen Ratios.							
	1:0.75	1:1.00	1:1.25	1:1.50	1:1.75	1:2.00	1:2.25	1:2.50
	Eqv. SiO_2	Eqv. SiO_2	Eqv. SiO_2	Eqv. SiO_2	Eqv. SiO_2	Eqv. SiO_2	Eqv. SiO_2	Eqv. SiO_2
0.000	0.3750	0.5000	0.6250	0.7500	0.8750	1.0000	1.1250	1.2500
0.005	0.3806	0.5075	0.6344	0.7613	0.8882	1.0150	1.1419	1.2688
0.010	0.3862	0.5150	0.6438	0.7726	0.9013	1.0300	1.1588	1.2876
0.015	0.3919	0.5225	0.6531	0.7837	0.9144	1.0450	1.1756	1.3063
0.020	0.3975	0.5300	0.6625	0.7950	0.9275	1.0600	1.1925	1.3250
0.025	0.4031	0.5375	0.6719	0.8063	0.9406	1.0750	1.2094	1.3437
0.030	0.4087	0.5450	0.6813	0.8175	0.9538	1.0900	1.2263	1.3625
0.035	0.4143	0.5525	0.6907	0.8289	0.9671	1.1050	1.2432	1.3813
0.040	0.4200	0.5600	0.7000	0.8400	0.9800	1.1200	1.2600	1.4000
0.045	0.4256	0.5675	0.7094	0.8513	0.9931	1.1350	1.2769	1.4188
0.050	0.4313	0.5750	0.7188	0.8625	1.0063	1.1500	1.2937	1.4375
0.055	0.4369	0.5825	0.7281	0.8737	1.0194	1.1650	1.3106	1.4562
0.060	0.4425	0.5900	0.7375	0.8850	1.0325	1.1800	1.3275	1.4750
0.065	0.4481	0.5975	0.7469	0.8963	1.0456	1.1950	1.3444	1.4938
0.070	0.4537	0.6050	0.7563	0.9075	1.0587	1.2100	1.3613	1.5125
0.075	0.4594	0.6125	0.7656	0.9187	1.0719	1.2250	1.3781	1.5313
0.080	0.4650	0.6200	0.7750	0.9300	1.0850	1.2400	1.3950	1.5500
0.085	0.4706	0.6275	0.7844	0.9413	1.0981	1.2550	1.4119	1.5687
0.090	0.4763	0.6350	0.7938	0.9525	1.1113	1.2700	1.4288	1.5875
0.095	0.4819	0.6425	0.8031	0.9637	1.1244	1.2850	1.4456	1.6063
0.100	0.4875	0.6500	0.8125	0.9750	1.1375	1.3000	1.4625	1.6250
0.105	0.4931	0.6575	0.8219	0.9863	1.1506	1.3150	1.4794	1.6437
0.110	0.4987	0.6650	0.8313	0.9975	1.1637	1.3300	1.4963	1.6625
0.115	0.5044	0.6725	0.8406	1.0087	1.1769	1.3450	1.5131	1.6812
0.120	0.5100	0.6800	0.8500	1.0200	1.1900	1.3600	1.5300	1.7000
0.125	0.5156	0.6875	0.8594	1.0313	1.2031	1.3750	1.5469	1.7188
0.130	0.5213	0.6950	0.8688	1.0425	1.2163	1.3900	1.5637	1.7375
0.135	0.5269	0.7025	0.8781	1.0537	1.2294	1.4050	1.5806	1.7563
0.140	0.5325	0.7100	0.8875	1.0650	1.2425	1.4200	1.5975	1.7750
0.145	0.5381	0.7175	0.8969	1.0763	1.2556	1.4350	1.6144	1.7937
0.150	0.5437	0.7250	0.9063	1.0875	1.2687	1.4500	1.6312	1.8125
0.155	0.5494	0.7325	0.9156	1.0987	1.2819	1.4650	1.6481	1.8312
0.160	0.5550	0.7400	0.9250	1.1100	1.2950	1.4800	1.6650	1.8500
0.165	0.5606	0.7475	0.9344	1.1212	1.3081	1.4950	1.6819	1.8687
0.170	0.5663	0.7550	0.9437	1.1325	1.3212	1.5100	1.6987	1.8875
0.175	0.5719	0.7625	0.9531	1.1437	1.3344	1.5250	1.7156	1.9062
0.180	0.5775	0.7700	0.9625	1.1550	1.3475	1.5400	1.7325	1.9250
0.185	0.5831	0.7775	0.9719	1.1663	1.3606	1.5550	1.7494	1.9438
0.190	0.5887	0.7850	0.9812	1.1775	1.3737	1.5700	1.7663	1.9625
0.195	0.5944	0.7925	0.9906	1.1887	1.3869	1.5850	1.7831	1.9812
0.200	0.6000	0.8000	1.0000	1.2000	1.4000	1.6000	1.8000	2.0000
0.205	0.6056	0.8075	1.0094	1.2113	1.4131	1.6150	1.8169	2.0187
0.210	0.6113	0.8150	1.0187	1.2225	1.4263	1.6300	1.8338	2.0375
0.215	0.6169	0.8225	1.0281	1.2337	1.4394	1.6450	1.8506	2.0563
0.220	0.6225	0.8300	1.0375	1.2450	1.4525	1.6600	1.8675	2.0750
0.225	0.6281	0.8375	1.0469	1.2563	1.4653	1.6750	1.8844	2.0937
0.230	0.6337	0.8450	1.0563	1.2675	1.4788	1.6900	1.9012	2.1125
0.235	0.6394	0.8525	1.0656	1.2787	1.4919	1.7050	1.9181	2.1312
0.240	0.6450	0.8600	1.0750	1.2900	1.5050	1.7200	1.9350	2.1500
0.245	0.6506	0.8675	1.0844	1.3012	1.5181	1.7350	1.9519	2.1688
0.250	0.6563	0.8750	1.0937	2.3125	1.5312	1.7500	1.9688	2.1875
0.255	0.6619	0.8825	1.1035	1.3237	1.5444	1.7650	1.9856	2.2062
0.260	0.6675	0.8900	1.1125	1.3350	1.5575	1.7800	2.0025	2.2250

Oxygen Ratios.						Distribution of Oxygen Between Bases. Total Basic Oxygen=1.	
1:2.75	1:3.00	1:3.25	1:3.50	1:3.75	1:4.00		
Eqv. SiO_2	Eqv. SiO_2	Eqv. SiO_2	Eqv. SiO_2	Eqv. SiO_2	Eqv. SiO_2	R O.	Al_2O_3
1.3750	1.5000	1.6250	1.7500	1.8750	2.0000	1.000	0.000
1.3957	1.5225	1.6494	1.7763	1.9032	2.0300	0.985	0.014
1.4163	1.5450	1.6738	1.8025	1.9313	2.0600	0.970	0.029
1.4369	1.5675	1.6981	1.8288	1.9594	2.0900	0.956	0.043
1.4575	1.5900	1.7225	1.8550	1.9875	2.1200	0.943	0.056
1.4781	1.6125	1.7469	1.8813	2.0157	2.1500	0.930	0.069
1.4987	1.6350	1.7713	1.9075	2.0438	2.1800	0.917	0.082
1.5194	1.6575	1.7957	1.9337	2.0718	2.2100	0.904	0.095
1.5400	1.6800	1.8200	1.9600	2.1000	2.2400	0.892	0.107
1.5606	1.7025	1.8444	1.9863	2.1281	2.2700	0.881	0.118
1.5813	1.7250	1.8688	2.0125	2.1563	2.3000	0.869	0.130
1.6019	1.7475	1.8931	2.0387	2.1844	2.3300	0.858	0.141
1.6225	1.7700	1.9175	2.0650	2.2125	2.3600	0.847	0.152
1.6431	1.7925	1.9419	2.0913	2.2406	2.3900	0.836	0.163
1.6637	1.8150	1.9663	2.1176	2.2688	2.4200	0.826	0.173
1.6844	1.8375	1.9906	2.1437	2.2969	2.4500	0.816	0.183
1.7050	1.8600	2.0150	2.1700	2.3250	2.4800	0.806	0.193
1.7256	1.8825	2.0394	2.1963	2.3531	2.5100	0.796	0.203
1.7463	1.9050	2.0638	2.2225	2.3813	2.5400	0.787	0.212
1.7669	1.9275	2.0881	2.2487	2.4094	2.5700	0.778	0.221
1.7875	1.9500	2.1125	2.2750	2.4375	2.6000	0.769	0.230
1.8081	1.9725	2.1369	2.3013	2.4656	2.6300	0.760	0.239
1.8287	1.9950	2.1613	2.3275	2.4937	2.6600	0.751	0.248
1.8494	2.0175	2.1856	2.3537	2.5219	2.6900	0.743	0.256
1.8700	2.0400	2.2100	2.3800	2.5500	2.7200	0.735	0.264
1.8906	2.0625	2.2345	2.4063	2.5781	2.7500	0.727	0.272
1.9113	2.0850	2.2588	2.4325	2.6063	2.7800	0.719	0.280
1.9319	2.1075	2.2831	2.4587	2.6344	2.8100	0.711	0.288
1.9525	2.1300	2.3075	2.4850	2.6625	2.8400	0.704	0.295
1.9731	2.1525	2.3319	2.5112	2.6906	2.8700	0.696	0.303
1.9937	2.1750	2.3562	2.5375	2.7187	2.9000	0.689	0.310
2.0144	2.1975	2.3806	2.5637	2.7469	2.9300	0.682	0.317
2.0350	2.2200	2.4050	2.5900	2.7750	2.9600	0.675	0.324
2.0556	2.2425	2.4294	2.6163	2.8031	2.9900	0.668	0.331
2.0763	2.2650	2.4537	2.6425	2.8312	3.0200	0.662	0.337
2.0969	2.2875	2.4781	2.6687	2.8594	3.0500	0.655	0.344
2.1175	2.3100	2.5025	2.6950	2.8875	3.0800	0.649	0.350
2.1381	2.3325	2.5269	2.7213	2.9156	3.1100	0.643	0.356
2.1587	2.3550	2.5512	2.7475	2.9437	3.1400	0.636	0.363
2.1794	2.3775	2.5756	2.7737	2.9719	3.1700	0.630	0.369
2.2000	2.4000	2.6000	2.8000	3.0000	3.2000	0.625	0.375
2.2206	2.4225	2.6244	2.8263	3.0281	3.2300	0.619	0.380
2.2412	2.4450	2.6487	2.8525	3.0562	3.2600	0.613	0.386
2.2619	2.4675	2.6731	2.8787	3.0844	3.2900	0.607	0.392
2.2825	2.4900	2.6975	2.9050	3.1125	3.3200	0.602	0.397
2.3031	2.5125	2.7219	2.9312	3.1406	3.3500	0.597	0.402
2.3238	2.5350	2.7462	2.9575	3.1688	3.3800	0.591	0.408
2.3444	2.5575	2.7706	2.9837	3.1969	3.4100	0.586	0.413
2.3650	2.5800	2.7950	3.0100	3.2250	3.4400	0.581	0.418
2.3853	2.6025	2.8194	3.0363	3.2531	3.4700	0.576	0.423
2.4062	2.6250	2.8437	3.0625	3.2812	3.5000	0.571	0.428
2.4269	2.6475	2.8681	3.0887	3.3094	3.5300	0.566	0.433
2.4475	2.6700	2.8925	3.1150	3.3375	3.5600	0.561	0.438

Equivalent of Alumina	Oxygen Ratios.							
	1:0.75	1:1.00	1:1.25	1:1.50	1:1.75	1:2.00	1:2.25	1:2.50
	Eqv. SiO_2	Eqv. SiO_2	Eqv. SiO_2	Eqv. SiO_2	Eqv. SiO_2	Eqv. SiO_2	Eqv. SiO_2	Eqv. SiO_2
0.265	0.6731	0.8975	1.1219	1.3462	1.5706	1.7950	2.0194	2.2437
0.270	0.6787	0.9050	1.1312	1.3575	1.5837	1.8100	2.0363	2.2625
0.275	0.6844	0.9125	1.1406	1.3688	1.5969	1.8250	2.0531	2.2812
0.280	0.6900	0.9200	1.1500	1.3800	1.6100	1.8400	2.0700	2.3000
0.285	0.6956	0.9275	1.1594	1.3912	1.6231	1.8550	2.0869	2.3187
0.290	0.7012	0.9350	1.1687	1.4025	1.6362	1.8700	2.1037	2.3375
0.295	0.7069	0.9425	1.1781	1.4137	1.6494	1.8850	2.1206	2.3562
0.300	0.7125	0.9500	1.1875	1.4250	1.6625	1.9000	2.1375	2.3750
0.305	0.7181	0.9575	1.1969	1.4362	1.6756	1.9150	2.1544	2.3937
0.310	0.7237	0.9650	1.2062	1.4475	1.6887	1.9300	2.1712	2.4125
0.315	0.7293	0.9725	1.2156	1.4587	1.7018	1.9450	2.1881	2.4312
0.320	0.7350	0.9800	1.2250	1.4700	1.7150	1.9600	2.2050	2.4500
0.325	0.7406	0.9875	1.2344	1.4812	1.7281	1.9750	2.2218	2.4687
0.330	0.7462	0.9950	1.2437	1.4925	1.7412	1.9900	2.2387	2.4875
0.335	0.7518	1.0025	1.2531	1.5037	1.7544	2.0050	2.2556	2.5062
0.340	0.7575	1.0100	1.2625	1.5150	1.7675	2.0200	2.2725	2.5250
0.345	0.7631	1.0175	1.2719	1.5262	1.7806	2.0350	2.2893	2.5437
0.350	0.7687	1.0250	1.2812	1.5375	1.7937	2.0500	2.3062	2.5625
0.355	0.7743	1.0325	1.2906	1.5487	1.8068	2.0650	2.3231	2.5812
0.360	0.7800	1.0400	1.3000	1.5600	1.8200	2.0800	2.3400	2.6000
0.365	0.7856	1.0475	1.3094	1.5712	1.8331	2.0950	2.3568	2.6187
0.370	0.7912	1.0550	1.3187	1.5825	1.8462	2.1100	2.3737	2.6375
0.375	0.7968	1.0625	1.3281	1.5937	1.8594	2.1250	2.3906	2.6562
0.380	0.8025	1.0700	1.3375	1.6050	1.8725	2.1400	2.4075	2.6750
0.385	0.8081	1.0775	1.3469	1.6162	1.8856	2.1550	2.4244	2.6937
0.390	0.8137	1.0850	1.3562	1.6275	1.8987	2.1700	2.4412	2.7125
0.395	0.8193	1.0925	1.3656	1.6387	1.9119	2.1850	2.4581	2.7312
0.400	0.8250	1.1000	1.3750	1.6500	1.9250	2.2000	2.4750	2.7500
0.405	0.8306	1.1075	1.3844	1.6612	1.9381	2.2150	2.4919	2.7687
0.410	0.8362	1.1150	1.3937	1.6725	1.9512	2.2300	2.5087	2.7875
0.415	0.8419	1.1225	1.4031	1.6837	1.9643	2.2450	2.5256	2.8062
0.420	0.8475	1.1300	1.4125	1.6950	1.9775	2.2600	2.5425	2.8250
0.425	0.8531	1.1375	1.4219	1.7062	1.9906	2.2750	2.5594	2.8437
0.430	0.8587	1.1450	1.4312	1.7175	2.0037	2.2900	2.5762	2.8625
0.435	0.8644	1.1525	1.4406	1.7287	2.0168	2.3050	2.5931	2.8812
0.440	0.8700	1.1600	1.4500	1.7400	2.0300	2.3200	2.6100	2.9000
0.445	0.8756	1.1675	1.4594	1.7512	2.0431	2.3350	2.6269	2.9187
0.450	0.8812	1.1750	1.4687	1.7625	2.0562	2.3500	2.6437	2.9375
0.455	0.8869	1.1825	1.4781	1.7737	2.0693	2.3650	2.6606	2.9562
0.460	0.8925	1.1900	1.4875	1.7850	2.0825	2.3800	2.6775	2.9750
0.465	0.8981	1.1975	1.4969	1.7962	2.0956	2.3950	2.6944	2.9937
0.470	0.9037	1.2050	1.5062	1.8075	2.1087	2.4100	2.7112	3.0125
0.475	0.9094	1.2125	1.5156	1.8187	2.1218	2.4250	2.7281	3.0312
0.480	0.9150	1.2200	1.5250	1.8300	2.1350	2.4400	2.7450	3.0500
0.485	0.9206	1.2275	1.5344	1.8413	2.1481	2.4550	2.7619	3.0688
0.490	0.9263	1.2350	1.5438	1.8525	2.1613	2.4700	2.7788	3.0875
0.495	0.9319	1.2425	1.5531	1.8638	2.1744	2.4850	2.7956	3.1063
0.500	0.9375	1.2500	1.5625	1.8750	2.1875	2.5000	2.8125	3.1250
0.505	0.9431	1.2575	1.5719	1.8863	2.2006	2.5150	2.8294	3.1438
0.510	0.9488	1.2650	1.5813	1.8975	2.2138	2.5300	2.8463	3.1625
0.515	0.9544	1.2725	1.5906	1.9088	2.2269	2.5450	2.8631	3.1813
0.520	0.9600	1.2800	1.6000	1.9200	2.2400	2.5600	2.8800	3.2000
0.525	0.9656	1.2875	1.6094	1.9313	2.2531	2.5750	2.8969	3.2188

Oxygen Ratios.						Distribution of Oxygen Between Bases. Total Basic Oxygen=1.	
1:2.75	1:3.00	1:3.25	1:3.50	1:3.75	1:4.00		
Eqv. SiO_2	Eqv. SiO_2	Eqv. SiO_2	Eqv. SiO_2	Eqv. SiO_2	Eqv. SiO_2	R O.	Al_2O_3
2.4681	2.6925	2.9169	3.1412	3.3656	3.5900	0.557	0.442
2.4888	2.7150	2.9412	3.1675	3.3937	3.6200	0.552	0.447
2.5094	2.7375	2.9656	3.1937	3.4219	3.6500	0.547	0.452
2.5300	2.7600	2.9900	3.2200	3.4500	3.6800	0.543	0.456
2.5506	2.7825	3.0144	3.2462	3.4781	3.7100	0.539	0.460
2.5712	2.8050	3.0387	3.2725	3.5062	3.7400	0.534	0.465
2.5919	2.8275	3.0631	3.2987	3.5344	3.7700	0.530	0.469
2.6125	2.8500	3.0875	3.3250	3.5625	3.8000	0.526	0.473
2.6337	2.8725	3.1119	3.3512	3.5906	3.8300	0.522	0.477
2.6537	2.8950	3.1362	3.3775	3.6188	3.8600	0.518	0.481
2.6743	2.9175	3.1606	3.4037	3.6469	3.8900	0.514	0.485
2.6950	2.9400	3.1850	3.4300	3.6750	3.9200	0.510	0.489
2.7156	2.9625	3.2093	3.4562	3.7031	3.9500	0.506	0.493
2.7362	2.9850	3.2337	3.4825	3.7312	3.9800	0.502	0.497
2.7568	3.0075	3.2581	3.5087	3.7593	4.0100	0.498	0.501
2.7775	3.0300	3.2825	3.5350	3.7875	4.0400	0.495	0.504
2.7981	3.0525	3.3069	3.5612	3.8156	4.0700	0.491	0.508
2.8187	3.0750	3.3312	3.5875	3.8437	4.1000	0.487	0.512
2.8393	3.0975	3.3556	3.6137	3.8718	4.1300	0.484	0.515
2.8600	3.1200	3.3800	3.6400	3.9000	4.1600	0.480	0.519
2.8806	3.1425	3.4044	3.6662	3.9281	4.1900	0.477	0.522
2.9012	3.1650	3.4287	3.6925	3.9562	4.2200	0.473	0.526
2.9218	3.1875	3.4531	3.7187	3.9843	4.2500	0.470	0.529
2.9425	3.2100	3.4775	3.7450	4.0125	4.2800	0.467	0.532
2.9631	3.2325	3.5019	3.7712	4.0406	4.3100	0.464	0.535
2.9837	3.2550	3.5262	3.7975	4.0687	4.3400	0.460	0.539
3.0043	3.2775	3.5506	3.8237	4.0968	4.3700	0.457	0.542
3.0250	3.3000	3.5750	3.8500	4.1250	4.4000	0.454	0.545
3.0456	3.3225	3.5994	3.8762	4.1531	4.4300	0.451	0.548
3.0662	3.3450	3.6237	3.9025	4.1810	4.4600	0.448	0.551
3.0869	3.3675	3.6481	3.9287	4.2091	4.4900	0.445	0.554
3.1075	3.3900	3.6725	3.9550	4.2375	4.5200	0.442	0.557
3.1281	3.4125	3.6969	3.9812	4.2656	4.5500	0.439	0.560
3.1487	3.4350	3.7212	4.0075	4.2937	4.5800	0.436	0.563
3.1694	3.4575	3.7456	4.0337	4.3218	4.6100	0.433	0.566
3.1900	3.4800	3.7700	4.0600	4.3500	4.6400	0.431	0.568
3.2106	3.5025	3.7944	4.0862	4.3781	4.6700	0.428	0.571
3.2312	3.5250	3.8187	4.1125	4.4062	4.7000	0.425	0.574
3.2519	3.5475	3.8431	4.1387	4.4343	4.7300	0.422	0.577
3.2725	3.5700	3.8675	4.1650	4.4625	4.7600	0.420	0.579
3.2931	3.5925	3.8919	4.1912	4.4906	4.7900	0.417	0.582
3.3137	3.6150	3.9162	4.2175	4.5187	4.8200	0.414	0.585
3.3343	3.6375	3.9406	4.2437	4.5468	4.8500	0.412	0.587
3.3550	3.6600	3.9650	4.2700	4.5750	4.8800	0.409	0.590
3.3756	3.6825	3.9894	4.2963	4.6031	4.9100	0.407	0.592
3.3963	3.7050	4.0138	4.3225	4.6313	4.9400	0.404	0.595
3.4169	3.7275	4.0381	4.3488	4.6594	4.9700	0.402	0.597
3.4375	3.7500	4.0625	4.3750	4.6875	5.0000	0.400	0.600
3.4581	3.7725	4.0869	4.4013	4.7156	5.0300	0.397	0.602
3.4788	3.7950	4.1113	4.4275	4.7438	5.0600	0.395	0.604
3.4994	3.8175	4.1356	4.4538	4.7719	5.0900	0.392	0.607
3.5200	3.8400	4.1600	4.4800	4.8000	5.1200	0.390	0.609
3.5406	3.8625	4.1844	4.5063	4.8281	5.1500	0.388	0.611

Equivalent of Alumina	Oxygen Ratios.							
	1:0.75	1:1.00	1:1.25	1:1.50	1:1.75	1:2.00	1:2.25	1:2.50
	Eqv. SiO_2	Eqv. SiO_2	Eqv. SiO_2	Eqv. SiO_2	Eqv. SiO_2	Eqv. SiO_2	Eqv. SiO_2	Eqv. SiO_2
0.530	0.9713	1.2950	1.6188	1.9425	2.2663	2.5900	2.9138	3.2375
0.535	0.9769	1.3025	1.6281	1.9538	2.2794	2.6050	2.9306	3.2563
0.540	0.9825	1.3100	1.6375	1.9650	2.2925	2.6200	2.9475	3.2750
0.545	0.9881	1.3175	1.6469	1.9763	2.3056	2.6350	2.9644	3.2938
0.550	0.9938	1.3250	1.6563	1.9875	2.3188	2.6500	2.9813	3.3125
0.555	0.9994	1.3325	1.6656	1.9988	2.3319	2.6650	2.9981	3.3313
0.560	1.0050	1.3400	1.6750	2.0100	2.3450	2.6800	3.0150	3.3500
0.565	1.0106	1.3475	1.6844	2.0213	2.3581	2.6950	3.0319	3.3688
0.570	1.0163	1.3550	1.6938	2.0325	2.3713	2.7100	3.0488	3.3875
0.575	1.0219	1.3625	1.7031	2.0438	2.3844	2.7250	3.0656	3.4063
0.580	1.0275	1.3700	1.7125	2.0550	2.3975	2.7400	3.0825	3.4250
0.585	1.0331	1.3775	1.7219	2.0663	2.4106	2.7550	3.0994	3.4438
0.590	1.0387	1.3850	1.7313	2.0775	2.4238	2.7700	3.1163	3.4625
0.595	1.0444	1.3925	1.7406	2.0888	2.4368	2.7850	3.1331	3.4813
0.600	1.0500	1.4000	1.7500	2.1000	2.4500	2.8000	3.1500	3.5000
0.610	1.0613	1.4150	1.7687	2.1225	2.4763	2.8300	3.1838	3.5375
0.620	1.0725	1.4300	1.7875	2.1450	2.5025	2.8600	3.2175	3.5750
0.630	1.0838	1.4450	1.8063	2.1675	2.5288	2.8900	3.2513	3.6125
0.640	1.0950	1.4600	1.8250	2.1900	2.5550	2.9200	3.2850	3.6500
0.650	1.1063	1.4750	1.8438	2.2125	2.5813	2.9500	3.3188	3.6875
0.660	1.1175	1.4900	1.8625	2.2350	2.6075	2.9800	3.3525	3.7250
0.670	1.1288	1.5050	1.8813	2.2575	2.6338	3.0100	3.3863	3.7625
0.680	1.1400	1.5200	1.9000	2.2800	2.6600	3.0400	3.4200	3.8000
0.690	1.1513	1.5350	1.9188	2.3025	2.6863	3.0700	3.4538	3.8375
0.700	1.1625	1.5500	1.9375	2.3250	2.7125	3.1000	3.4875	3.8750
0.710	1.1738	1.5650	1.9563	2.3475	2.7388	3.1300	3.5213	3.9125
0.720	1.1850	1.5800	1.9750	2.3700	2.7650	3.1600	3.5550	3.9500
0.730	1.1963	1.5950	1.9938	2.3925	2.7913	3.1900	3.5888	3.9875
0.740	1.2075	1.6100	2.0125	2.4150	2.8175	3.2200	3.6225	4.0250
0.750	1.2188	1.6250	2.0313	2.4375	2.8438	3.2500	3.6563	4.0625
0.760	1.2300	1.6400	2.0500	2.4600	2.8700	3.2800	3.6900	4.1000
0.770	1.2413	1.6550	2.0688	2.4825	2.8963	3.3100	3.7238	4.1375
0.780	1.2525	1.6700	2.0875	2.5050	2.9225	3.3400	3.7575	4.1750
0.790	1.2638	1.6850	2.1063	2.5275	2.9488	3.3700	3.7913	4.2125
0.800	1.2750	1.7000	2.1250	2.5500	2.9750	3.4000	3.8250	4.2500
0.810	1.2863	1.7150	2.1438	2.5725	3.0013	3.4300	3.8588	4.2875
0.820	1.2975	1.7300	2.1625	2.5950	3.0275	3.4600	3.8925	4.3250
0.830	1.3088	1.7450	2.1813	2.6175	3.0538	3.4900	3.9263	4.3625
0.840	1.3200	1.7600	2.2000	2.6400	3.0800	3.5200	3.9600	4.4000
0.850	1.3313	1.7750	2.2188	2.6625	3.1063	3.5500	3.9938	4.4375
0.860	1.3425	1.7900	2.2375	2.6850	3.1325	3.5800	4.0275	4.4750
0.870	1.3538	1.8050	2.2563	2.7075	3.1588	3.6100	4.0613	4.5125
0.880	1.3650	1.8200	2.2750	2.7300	3.1850	3.6400	4.0950	4.5500
0.890	1.3763	1.8350	2.2938	2.7525	3.2113	3.6700	4.1288	4.5875
0.900	1.3875	1.8500	2.3125	2.7750	3.2375	3.7000	4.1625	4.6250
0.910	1.3988	1.8650	2.3313	2.7975	3.2638	3.7300	4.1963	4.6625
0.920	1.4100	1.8800	2.3500	2.8200	3.2900	3.7600	4.2300	4.7000
0.930	1.4213	1.8950	2.3688	2.8425	3.3163	3.7900	4.2638	4.7375
0.940	1.4325	1.9100	2.3875	2.8650	3.3425	3.8200	4.2975	4.7750
0.950	1.4438	1.9250	2.4063	2.8875	3.3688	3.8500	4.3313	4.8125
0.960	1.4550	1.9400	2.4250	2.9100	3.3950	3.8800	4.3650	4.8500
0.970	1.4663	1.9550	2.4438	2.9325	3.4213	3.9100	4.3988	4.8875
0.980	1.4775	1.9700	2.4625	2.9550	3.4475	3.9400	4.4325	4.9250
0.990	1.4888	1.9850	2.4813	2.9775	3.4738	3.9700	4.4663	4.9625
1.000	1.5000	2.0000	2.5000	3.0000	3.5000	4.0000	4.5000	5.0000

Oxygen Ratios.						Distribution of Oxygen Between Bases. Total Basic Oxygen=1.	
1:2.75	1:3.00	1:3.25	1:3.50	1:3.75	1:4.00		
Eqv. SiO_2	Eqv. SiO_2	Eqv. SiO_2	Eqv. SiO_2	Eqv. SiO_2	Eqv. SiO_2	R O.	Al_2O_3
3.5613	3.8850	4.2088	4.5325	4.8563	5.1800	0.386	0.613
3.5819	3.9075	4.2331	4.5588	4.8844	5.2100	0.383	0.616
3.6025	3.9300	4.2575	4.5850	4.9125	5.2400	0.381	0.618
3.6231	3.9525	4.2819	4.6113	4.9406	5.2700	0.379	0.620
3.6438	3.9750	4.3063	4.6375	4.9688	5.3000	0.377	0.622
3.6644	3.9975	4.3306	4.6638	4.9969	5.3300	0.375	0.624
3.6850	4.0200	4.3550	4.6900	5.0250	5.3600	0.373	0.626
3.7056	4.0425	4.3794	4.7163	5.0531	5.3900	0.371	0.628
3.7263	4.0650	4.4038	4.7425	5.0813	5.4200	0.369	0.630
3.7469	4.0875	4.4281	4.7688	5.1094	5.4500	0.366	0.633
3.7675	4.1100	4.4525	4.7950	5.1375	5.4800	0.364	0.635
3.7881	4.1325	4.4769	4.8213	5.1656	5.5100	0.362	0.637
3.8088	4.1550	4.5013	4.8475	5.1938	5.5400	0.361	0.638
3.8294	4.1772	4.5256	4.8738	5.2219	5.5700	0.359	0.640
3.8500	4.2000	4.5500	4.9000	5.2500	5.6000	0.357	0.642
3.8913	4.2450	4.5988	4.9525	5.3063	5.6600	0.353	0.646
3.9325	4.2900	4.6475	5.0050	5.3625	5.7200	0.349	0.650
3.9738	4.3350	4.6963	5.0575	5.4188	5.7800	0.346	0.653
4.0150	4.3800	4.7450	5.1100	5.4750	5.8400	0.342	0.657
4.0563	4.4250	4.7938	5.1625	5.5313	5.9000	0.338	0.661
4.0975	4.4700	4.8425	5.2150	5.5875	5.9600	0.335	0.664
4.1388	4.5150	4.8913	5.2675	5.6438	6.0200	0.332	0.667
4.1800	4.5600	4.9400	5.3200	5.7000	6.0800	0.328	0.671
4.2213	4.6050	4.9888	5.3725	5.7563	6.1400	0.325	0.674
4.2625	4.6500	5.0375	5.4250	5.8125	6.2000	0.322	0.677
4.3038	4.6950	5.0863	5.4775	5.8688	6.2600	0.319	0.680
4.3450	4.7400	5.1350	5.5300	5.9250	6.3200	0.316	0.683
4.3863	4.7850	5.1838	5.5825	5.9813	6.3800	0.313	0.686
4.4275	4.8300	5.2325	5.6350	6.0375	6.4400	0.310	0.689
4.4688	4.8750	5.2813	5.6875	6.0938	6.5000	0.307	0.692
4.5100	4.9200	5.3300	5.7400	6.1500	6.5600	0.304	0.695
4.5513	4.9650	5.3788	5.7925	6.2063	6.6200	0.302	0.697
4.5925	5.0100	5.4275	5.8450	6.2625	6.6800	0.299	0.700
4.6338	5.0550	5.4763	5.8975	6.3188	6.7400	0.296	0.703
4.6750	5.1000	5.5250	5.9500	6.3750	6.8000	0.294	0.706
4.7163	5.1450	5.5738	6.0025	6.4313	6.8600	0.291	0.708
4.7575	5.1900	5.6225	6.0550	6.4875	6.9200	0.289	0.710
4.7983	5.2350	5.6713	6.1075	6.5438	6.9800	0.286	0.713
4.8400	5.2800	5.7200	6.1600	6.6000	7.0400	0.284	0.715
4.8813	5.3250	5.7688	6.2125	6.6563	7.1000	0.281	0.718
4.9225	5.3700	5.8175	6.2650	6.7125	7.1600	0.279	0.720
4.9638	5.4150	5.8663	6.3175	6.7688	7.2200	0.277	0.722
5.0050	5.4600	5.9150	6.3700	6.8250	7.2800	0.274	0.725
5.0463	5.5050	5.9638	6.4225	6.8813	7.3400	0.272	0.727
5.0875	5.5500	6.0125	6.4750	6.9375	7.4000	0.270	0.729
5.1288	5.5950	6.0613	6.5275	6.9938	7.4600	0.268	0.731
5.1700	5.6400	6.1100	6.5800	7.0500	7.5200	0.265	0.734
5.2113	5.6850	6.1588	6.6325	7.1063	7.5800	0.263	0.736
5.2525	5.7300	6.2075	6.6850	7.1625	7.6400	0.261	0.738
5.2938	5.7750	6.2563	6.7375	7.2188	7.7000	0.259	0.740
5.3350	5.8200	6.3050	6.7900	7.2750	7.7600	0.257	0.742
5.3763	5.8650	6.3538	6.8425	7.3313	7.8200	0.255	0.744
5.4175	5.9100	6.4025	6.8950	7.3875	7.8800	0.253	0.746
5.4588	5.9550	6.4513	6.9475	7.4400	7.9400	0.251	0.748
5.5000	6.0000	6.5000	7.0000	7.5000	8.0000	0.250	0.750

according to the two columns on the extreme right, the whole ratio would be nearly:

Oxygen (Base): Oxygen (Acid):: 0.539 (RO)+0.460 (Al_2O_3):3.50.

But this is not exact. By interpolation we obtain for exact value 0.287 Al_2O_3 at 3.5 oxygen ratio, 3.2562. But this is more silica than we have present, so by interpolation between this and the next lower value, we obtain 1:3.475.

It is not likely that much time will be saved in this latter operation, over computing the whole problem at once, but it also may be said that one can read at a glance the essential fact that the result will be slightly under 3.5, which is, in most cases, all that is needed.

Problem 3—To construct a series of glazes in which the effect of variation of alumina content, and oxygen ratio on the production of a matt glaze is to be studied.

It is in such a problem that this table is the most useful. For each equivalent of alumina chosen, the silica equivalent required for each O. R. can be readily found in the table.

Aside from the saving of time and work in the construction of such a series of experiments, the use of this table tends towards a more logical and complete series of glazes. The value and importance of this last item can be appreciated only by those who have tried to work without such an aid.

A CONTRIBUTION TO THE TECHNOLOGY OF DRYING.

BY

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While designing a brick-dryer to utilize the waste heat from cooling kilns recently, the scantiness of the literature or published data bearing upon the calculation of the consumption of heat in driers, was keenly felt. Information relating to the physical properties of heat and air are to be found in various books and physical treatises, but nowhere has the information been found in convenient form for easy application to the actual computations of drying problems.

The best discussion of this problem is found in the "Collected Writings of Seger," Vol. I, pp. 251-271, but Seger does not attempt to form a heat balance, some of his data are not the same as are now accepted by physicists, and the exact method of his procedure is not always very clear.

The following study is an extension and an amplification of Seger's general method to a characteristic American problem in dryer economy, and is put forward merely as a possible convenience and help to others who may be undertaking similar problems.

From plants in actual operation using waste heat from cooling kilns for drying purposes, it is a proven fact that 1000 burned bricks contain more than sufficient heat to dry 1000 brick under ordinary practical conditions.

Primarily, this calculation was made to show what can be done in the way of drying by using waste heat from cooling kilns, but the methods and results will be found to apply equally to dryers, where the heat is generated in other ways.

Seger has well stated the fundamental physical principles underlying drying, but the actual operation involves a consideration of other factors to be dealt with. In practical work, the theoretical principles cannot be rigidly carried out as calculated,

but in all drying operations, the theoretical calculations should be first made, and a sufficient margin allowed to cover the losses and changes due to the necessary imperfections of the process.

General Considerations of the Properties of Heat, Air and Moisture.

1st Heat. The fundamental factor in drying is heat. We usually think of heat in terms of its intensity, by temperature. In drying considerations, the amount or quantity of heat is most important. Temperature alone gives no clue as to the quantity which must be measured from a knowledge of the quantity of the heated substance and its characteristic capacity to absorb heat, or its *specific heat.*

The most convenient unit of quantity is the metric unit or calorie, or the amount of heat necessary to raise 1 Kg. of pure water from 0°C to 1°C.

2nd—Evaporation. In order to evaporate water, a certain amount of heat is required, which is always the same for the same quantity at the same temperature. The amount required increases as the temperature at which the evaporation takes place increases. Evaporation takes place at any and all temperatures, but only slowly at low temperatures and more rapidly as the temperature rises.

3rd—Tension of Water Vapor. When water is evaporated at temperatures below boiling, and in air which is confined, it soon happens that no further evaporation can take place. This is explained by the tension or pressure of water vapor. Above boiling temperatures this pressure is greater than that of the atmosphere, and the vapor is able to drive the atmosphere out of an inclosed chamber, if any outlet is given. Below boiling temperatures, this pressure is less than atmospheric tension. The tension of water is a fixed amount at any temperature, and limits the amount of vapor that can exist in a given space at that temperature.

4th—Dewpoint. As soon as the amount of moisture in a given space becomes so great that its vapor tension exceeds the limit for that temperature, the excess vapor is deposited as water. By heating fully saturated air, its power to take up moisture is increased, for the original amount of moisture contained is not

altered, while the vapor carrying capacity, or vapor tension, is raised. When the air escapes from a drier fully saturated, we are securing the greatest efficiency from it.

5th—Humidity. By humidity we mean the percent of saturation of air at any temperature. If air is fully saturated it has an humidity of 100%. From records kept by the U. S. Signal Service, we may assume the average temperature of the air in this country to be 10°C, and its humidity to be 75%.

Other physical principles will be explained as they arise in the process of calculation.

Statement of the Problem.

1. To dry 50,000 stiff mud bricks per day, wet weight, 9 pounds each.

2. The air conveying the heat into the dryer is to be heated up from 10°C and 75% humidity to 80°C. by dilution with hot air from kiln. The air enters the dryer at 80°C, and having given up its heat to evaporate the water, it leaves the dryer at a temperature just above its dewpoint.

3. The brick to enter the dryer at 10°C and leave at 80°C.

4. The finishing temperature of the kilns is assumed at 1300°C.

The calculation is most conveniently divided as follows:

I.—Heat Consumption.
- *a* Evaporation of water.
- *b* Heat carried out by clay.
- *c* Heat carried out by iron brick-cars.
- *d* Radiation from exterior of dryer.

II—Air volume required.

III—Heat loss, i. e. heat carried out by air.

IV—Available heat.

I. HEAT CONSUMPTION.

a—Heat Units Required to Evaporate Water in Brick.

50,000 brick, weighing 9 pounds each, make a total weight of 450,000 pounds. Assuming that the average water content of stiff mud brick is 22½% of the wet weight, then (450,000x0.225) 50,000 brick contain 101,250 pounds of water. 1 kilogram is

equal to 2.20 pounds. Then 101,250 pounds equals 46,020 kilograms water. This amount is to be evaporated and carried out of the dryer every 24 hours.

By referring to Table I at the end of this paper, we see that at average dryer temperatures, 1 kilogram of water requires 620 heat units to evaporate it.

e. q. $46{,}020 \times 620 = 28{,}532{,}400$ H. U. to evaporate the water in the brick.

b—Heat Carried Out by Clay in Bricks.

Total weight of bricks 450,000 pounds, multiplied by the percent of dry clay (100—22.5) 77.5%, gives 348,750 pounds of clay leaving the dryer per day. 348,750 pounds=158,522 kilograms.

One pound of clay will absorb only one-fifth as much heat as one pound of water. To reduce this clay heat to a basis comparable with water, we use this factor 0.2, called the specific heat. The clay enters dryer at 10°C and leaves at 80°C, a difference of 70°C.

e. q. The clay × its specific heat × its gain in temperature equals the heat units carried out or $158{,}522 \times 0.2 \times 70 = 2{,}219{,}280$ H. U. carried out by clay.

c—Heat Carried Out by Iron Dryer Cars.

100 cars, weighing 380 pounds each, enter at 10°C and leave at 80°C. They must be heated 70°C. The specific heat of iron= 0.1124. Reducing the weight of cars to kilograms, we have

$$\frac{100 \times 380 \times 0.1124 \times 70}{2.20} = 135{,}901.6 \text{ H. U.}$$

d—Radiation.

There is no well determined amount or factor for the calculation of radiation losses in dryers. The nearest parallel can be drawn from steam boilers, in which the heat balance has been calculated very carefully for a long time past. In the boiler this radiation loss, taken by difference between total heat generated and that whose use can be accounted for, is about 10% in average practice.

The brick dryer works at a very much lower temperature than any boiler, and its radiation should be lower on that account, but it is enormously extended in radiating surface compared to the small compact boiler setting. Hence for lack of better figures, we assume that the radiation would be the same, viz. 10% of the total heat used.

The heat used so far is

a	28,532,400	H. U.
b	2,219,280	H. U.
c	135,901	H. U.
Sum	30,887,581	H. U.
Add 10%....	3,088,758	H. U.
Total.....	33,976,339	H. U.

II—CALCULATION OF AIR VOLUME REQUIRED.

It is first necessary to find the available heat in 1 cubic meter of air, entering the dryer at 80°C, and leaving it at the most economical temperature.

We shall assume 30°C as the temperature at which the air leaves the dryer. For all practical purposes we may assume that the available heat comes from the dry air alone. There are a few other calculable factors, but they are of no importance.

By substituting in the formula I A, (see appendix), we have the weight of the dry air in kilogrammes per cubic meter as:

$$1.293187 \times \frac{P}{760} \times \frac{1}{1+.00367 \times t}$$

The value of P is found by subtracting the vapor tension at 30°C, as given in Table II, from 760, which is the barometric pressure in millimeters of mercury under standard conditions.

We find that the weight of dry air in 1 cubic meter of saturated atmosphere at 30°C is 1.116 kilograms.

The specific heat of air is 0.237 compared to water as 1. Therefore, this quantity of dry air (which entered at 30°C) will contain when heated up to 80°

$$1.116 \text{ kilograms} \times 0.237 \times 80 = 21.16 \text{ heat units.}$$

On escaping at 30°C, after giving up its available heat to the work of the dryer, the same weight of dry air will carry out

$$1.116 \text{ kilograms} \times 0.237 \times 30 = 7.39 \text{ heat units.}$$

The amount of heat available for work in the dryer, per cubic meter of escaping atmosphere, is

$$21.16-7.93=13.23 \text{ heat units.}$$

The heat work which this amount will accomplish in evaporating water, is reached as follows:

The average consumption of heat in evaporation of 1 kilogram of water, at temperatures occurring in closed dryers, is 620 heat units. It varies with the temperature at which evaporation occurs, being 606.5 at 0°C and 637 at 100°C. At ordinary atmospheric temperatures, for open air drying, it is about 610, which figure Seger used in all of his articles. But for closed dryers, this figure is too low—620 is much nearer the truth.

Now, if 620 heat units are required to evaporate 1 kilogram of water then $\frac{13.23}{6.20}=.0213$ kilograms or 21.3 grams, which may be evaporated by the heat given up in cooling 1 cubic meter from 80° to 30°C.

We must consider that every cubic meter with which we started at 10°C contained 75% of all the water it was capable of holding.

From Table III we find that 1 cubic meter of saturated air at 10°C contains 9.33 grams of water, (calculated from formula I. B). At 75% humidity, 1 cubic meter contains $9.33\times.75=7.00$ grams.

The air leaves the dryer at 30°, and we have found how much water each cubic meter at 30°C is capable of evaporating. We must next find how much of the water carried out is the original moisture carried in by the air, and how much is water evaporated from the clay wares.

Since air expands on heating, it follows that if 1 cubic meter were heated up from 10° to 30°C, and no more water was brought in contact with it, that the original quantity of water, though identical in actual amount, would be less per cubic meter, since it is now spread over a larger volume.

By formula II,

$$V'=V\,[1+0.00367\,(t-t')]$$

we find the increase in volume of one cubic meter raised from 10° to 30°C.

$$V' = 1[1 + 0.00367\ (30 - 10)]$$
$$V' = 1.0734 \text{ cubic meters}$$

and the amount of the original moisture per cubic meter would be

$$\frac{7.00}{1.0734} = 6.52 \text{ grams.}$$

Each cubic meter of escaping atmosphere at 30°C must therefore carry out

21.30 grams evaporated water
6.52 grams original water

27.82 grams total water

By reference to Table III, we find that 1 cubic meter of air at 30°C and 100% humidity is capable of holding 30.11 grams of water, so we have a safe margin in the case assumed.

It has already been shown that 46,020 kilogrammes of water are to be evaporated, and that 1 cubic meter of air, cooling from 80°C to 30°C can evaporate 21.3 grams.

Hence $\frac{46020}{0.0213} = 2{,}160{,}563$ cubic meters of air required for evaporation processes alone.

But the evaporation of water is not the only need for heat. The clay enters cold and leaves hot, carrying out much heat; likewise the iron cars.

One cubic meter of air entering dryer at 80°C and leaving at 30°C gives up 13.23 available heat units. The clay, the cars, and the losses by radiation have been shown to amount collectively to 5,443,938 H. U.

Hence $\frac{5{,}443{,}938}{13.23} = 411{,}483$ cubic meters of air at 30°C are needed to supply this heat. Adding, we obtain 2,572,046 cubic meters as the total requirement.

If, now, the air entered the dryer at the temperature at which it leaves it, then the figures just reached would be the final volume of air required for the process. But the air enters at 80°C, and its volume at this temperature is (Formula II)

greater than at 30°C in the proportion of 1.183 to 1.000. Hence the actual volume of the incoming air to be handled will be

$$2{,}572{,}046 \times 1.1835 = 3{,}044{,}016 \text{ cubic meters.}$$

Throwing this into cubic feet per minute, we have

$$\frac{3{,}044{,}016 \times 35.3}{24 \times 60} = 74{,}620 \text{ cu. ft. per minute at the inlet or hot end.}$$

Also $\frac{2{,}572{,}046 \times 35.3}{24 \times 60} = 63{,}050$ cubic feet per minute at the outlet or cold end.

III.—LOSSES OF HEAT CARRIED OUT BY THE AIR PASSING THROUGH THE DRYER.

The air enters the dryer, according to the terms of the problem, at 10°C, but is heated up by the addition of air which has been used in cooling the kilns, until the mixture has a temperature of 80°C. But, since this hot air entered the kiln at the same outside temperature, viz., 10°C, it makes no difference so far as the calculation is concerned where the air got its heat. It was originally at 10°C and it passed through the dryer, escaping at 30°C. Hence it carries out the heat corresponding to a 20 degree raise in temperature.

We are dealing, however, with the air alone, and not with the moisture contents which goes to make up the atmosphere. Its heat is covered in other calculations.

One cubic meter of saturated atmosphere at 30°C contains (Formula I) 1.116 kilograms of dry air, and this carries out $1.116 \times 0.237 \times 30 = 7.93$ heat units per cubic meter. The same weight of air brought in

$$1.116 \times 0.237 \times 10 = 2.645 \text{ heat units.}$$

Subtracting, we have 5.285 heat units per cubic meter, which must be supplied to the air, and which passes through the dryer without effect. On the whole volume, this amounts to

$$2{,}572{,}046 \times 5.285 = 13{,}593{,}363 \text{ heat units.}$$

Adding the results of Sections I and III, we have

	33,976,984
	13,593,363
Total heat requirements	47,556,247 H. U. for all purposes.

IV.—AVAILABLE HEAT.

There are a number of separate items, but after all there is but one source, viz., the heat units unlocked by the combustion of fuel. This is given out in the fire box, taken up by the combustion gases, absorbed by the bricks and kiln lining in small part, and to a large extent is liberated in the vast ocean of free air in which it becomes dissipated without observable effect.

Of the heat thus rescued from the combustion gases, a part is used in decomposing the minerals of the clay, and bringing them up to the point where combination ensues; part is carried through the kiln walls and is radiated away into space. At the end of the burning process, the kiln and its contents are at a high temperature throughout, and this heat is theoretically all available, i. e., it has no further chemical work to do and must escape into the air, usefully or uselessly.

Whatever of this heat may be rescued from the cooling ware and kiln is therefore pure gain, and whatever is not thus obtained, must be supplied either by burning fresh fuel or saving it from the waste of other processes, chiefly power generation.

The calculations are as follows:

50,000 Bricks$\times$9 pounds=450,000 pounds original wet weight.

Assuming a loss of 22.5% in drying, which is an average figure, we would have

$$450{,}000\times 0.775 = 348{,}750 \text{ pounds after drying.}$$

This again is reduced by 8% chemical water and other volatile substances lost in burning—

$$348{,}750\times 0.92 = 320{,}850$$

$$\frac{320850}{2.20} = 145840.9 \text{ kilograms, burnt weight}$$

145,840.9 kg.$\times$.2 spec. heat$\times$1100°C=32,084,998 H. U.

The 1100°C is used on the assumption that if the kiln is at 1300°C at the finish, that it will not be feasible to use its waste heat completely down to the atmospheric temperature again—in fact, as the temperature approaches the atmospheric, a larger portion of the air for the dryer would have to pass through it, until finally all would pass through, and then soon the kiln would be no longer able to maintain a temperature of 80°C. Accordingly, it was assumed that at 200°C no further use of the kiln would be possible. Hence 1300°—200°=1100° available temperature.

Besides the contents of the kiln, the walls, floor, fire boxes and flues between the kiln and the stack up to the point where the air is taken off to the dryer, become available sources for heating the air. To get at this source, a calculation will be necessary.

The kiln is 30 feet in diameter; 7 feet high to the spring of the arch. Assuming that the floor is equivalent to a solid layer 1 foot thick, and that of the thick vertical walls, the inside 12 inches is up to 1100 degrees actual or 900° available temperature, and that of the crown, 9 inches is available at 900°, we have a basis for calculation.

Area of kiln floor=30×30×0.7854=706.86 square feet.

706.86×1 foot deep=706.86 cubic feet in the floor.

Circumference of the kiln=30×3.1416=94.248 feet.

94.248×7×1=659.736 cubic feet available brick work in the side walls.

The crown may be taken at approximately 1¼×the area of the bottom=833.525 sq. feet. 833.525×¾ foot thick=662.643 cubic feet in crown.

Summing up, we have

Floor	706.860
Walls	659.736
Crown	662.643
Total	2029.239 cubic feet of masonry.

1 brick, 4½ inches × 2½ inches × 8½ inches=95.625 cubic inches.

1 cubic foot=18.07 bricks.

2029.239×18.07=36,668.35 bricks.

36,668.35×8 pounds=293,346.8 pounds.

$$\frac{293,346.8}{2.20}=133,339 \text{ kilograms.}$$

133,339 kg.×0.2 (specific heat)×900° available temperature will generate 24,000,424 heat units from the kiln itself.

Kiln and charge	56,084,422 H. U.
Required for drying	47,556,247 H. U.
Available margin	8,528,175 H. U.

Thus it is seen, that under the assumed conditions, there is a comfortable surplus of heat over that required by the fixed

physical laws. However, the conditions assumed are all good or favorable to economical drying.

ASSUMING UNFAVORABLE CONDITIONS.

Suppose, instead of using the heat of our air supply completely or nearly so, in doing effective work in the dryer, we allow the gases to escape from the dryer at 50°C instead of 30°.

The amount of heat required for I and II remain unaltered at 33,976,339 H. U.

But in III, we have dry air in 1 cubic meter saturated air at 50°C= (Formula I) 0.960 kg. This weight at 80° brought in $0.96 \times 0.237 \times 80 = 18.2$ H. U.

The same weight at 50°C holds

$$0.96 \times 0.237 \times 50 = 11.38 \text{ H. U.}$$

Available heat=18.2—11.38=6.82 H. U. per cubic meter.

Referring to Table IV we see that 1 cubic meter of saturated air at 50°C, is capable of carrying out 76.34 grams of water above what it originally held when it entered at 10°C.

We have 46,020 kilograms of water to be carried out. $\frac{46,020,000}{76.34}$ =602,829 cubic meters of air to carry out this quantity of water.

Each cubic meter in cooling from 80° to 50° gives up 6.82 H. U.

$$602,829 \times 6.82 = 4,111,293 \text{ H. U. brought in.}$$

But in order to evaporate water, heat clay, cars, etc., we must supply 33,976,339 H. U. Hence we have 29,810,755 H. U. deficiency that must be supplied by using extra volumes of air that are not required to carry out water.

$$\frac{29,810,755}{6.82} = 4,371,078 \text{ cubic meters required.}$$

Now these 4,371,078 cubic meters also carry out heat, which is a dead loss, since this air is not required for removing water.

1 cubic meter of air at 50°C holds 11.38 H. U. At 10°C, this weight of air brought in 2.28 H. U. The loss per cubic meter is then 9.10 H. U.

$4,371,078 \times 9.10 = 39,776,809$ H. U. required to heat up the air from atmospheric temperature, to the point where it escapes

from the dryer. The total heat required is the sum, 33,976,339+ 39,776,809=73,698,857 H. U. But we have only 56,084,422 H. U., leaving a deficiency of 17,614,435 H. U.

This clearly shows that the process would not be feasible under the conditions assumed. The volume of air required to carry out the water is so much smaller (602,829 cubic meters vs. 2,572,046) and the amount of heat it brings in is so much smaller (4,111,293 vs. 33,976,339 H. U.) that it leaves a tremendous deficiency, which must be met by using air for heating purposes only (i. e., it has no evaporation to do). But as we realize only a part of the heat of this air, (6.82 H. U. per cubic meter) and lose all heat between the point of discharge and atmospheric, (9.10 H. U. per cubic meter) it follows that we must use fuel at a great disadvantage, losing more than we utilize throughout.

It is probable that exceptions may be taken to some of the assumptions made in the above method, but no definite rule can be laid down for all conditions. The amount of radiation depends entirely upon the conditions governing each individual plant.

We believe we are justified in assuming 100% humidity or complete saturation for the air leaving dryer, for in many cases of dryers in actual practice, difficulty is met from the air becoming super-saturated and depositing its moisture as dew on the ware.

It may be argued that the time of drying would influence the degree of saturation. As a general thing, this depends more upon the clay. If a clay can be dried in 24 hours, it is likely that the time required for the air to flow through the dryer would completely saturate it, depending to some extent, of course, upon the length of dryer. Certainly 36 hour or 48 hour periods of drying would be ample.

Another slight error is in the assumption of the specific heat for burned clay. This factor is not known, and probably varies for different clays, and possibly for different methods of manufacture.

But with all the unavoidable errors it is hoped that this article may in a measure meet the needs of practical men who have such problems to consider. It does not follow, however, that any amount of clay ware can be dried exactly as calculated. It

depends upon the kind of clay, shape, size, and other physical conditions.

In drying clothes, paper, etc., the end in view is simply to remove the water, and almost any physical means of drying may be used to reach this end. But in ceramics, this cannot be done. One all-important condition is attached to the process of getting out the water, i. e., that of having the dried product in perfect condition.

This fact cannot be sacrificed to economy of fuel, space or time, but this end must be reached by the best possible means.

Still, however much the actual conditions influence each specific case, all cases should be based upon the theoretical considerations. The results will certainly never reach up to these, but the aim should be to approach these conditions as closely as possible. And the theoretical conditions form the only strictly comparable basis for all cases.

By referring to the appended tables, an approximate idea can be reached for any given case, with but little calculation.

FORMULAE.

Formula I—For finding the proportions of air and water vapor in any volume of saturated atmosphere at any temperature.

$$A = 1.293187 \times \frac{P}{760} \times \frac{1}{1+at}$$

$$B = 1.293187 \times \frac{P'}{760} \times \frac{1}{1+at} \times 0.6235$$

In which

A=Weight of air in kilograms in 1 cubic meter of saturated atmosphere.

B=Weight of water vapor in kilograms in 1 cubic meter of saturated atmosphere.

P′=Tension of water vapor at temperature t (given in Table III).

P=760 (standard pressure of atmosphere in millimeters of mercury)—tension of water vapor at t°C.

1.293187=Weight in kilograms of 1 cubic meter of dry air at 0°C and 760 m.m. barometric pressure.

0.6235=Specific weight of water vapor, where dry air is equal to 1.

$\frac{1}{1+at}$=Correction for volume of a gas due to changes of temperature, in which a=0.00367=coefficient of expansion of a gas for one degree centigrade, i. e., 1 cubic meter at 0°C becomes 1.00367 cubic meters, at 1°C and 1.00734 at 2°C, etc.

t=temperature of the observations.

Formula II—For finding increase in volume of air due to increase in its temperature.

$$V'=V\ [1+a\ (T-t)\ ]$$

in which:—

V′=Volume of the air at the temperature T.

V=Volume of the air at the temperature t.

a=.00367 as explained in Formula I.

Similarly, where we wish to obtain the volume of a gas, decreased by reduction of temperature, we have

$$V=\frac{V'}{1+a\ (T-t)}$$

Formula III—Converting temperatures in Centigrade to Fahrenheit.

$$°F \text{ to } °C=\frac{5\ (F-32)}{9}$$

$$°C \text{ to } °F=\frac{9\ C}{5}+32$$

Formula IV,

1 kilogram=2.20 pounds.

1 cubic meter=35.3 cubic feet.

TABLE I.

Showing heat consumption in converting 1 unit of water from 0°C to water vapor at the temperature given.

Temp. C°	Temp. F°	Heat units required	Temp. C°	Temp. F°	Heat units required
0	32	606.5	60	140	624.8
10	50	609.5	70	158	627.8
20	68	612.6	80	176	630.9
30	86	615.7	90	194	633.9
40	104	618.7	100	212	637.0
50	122	621.7	...	...	.....

TABLE II.

Giving the vapor tension of water at different temperatures.

Temp C°	Temp. F°	Tensions in m. m. Mercury	Temp. C°.	Temp. F°	Tension in m. m. Mercury
0	32	4.56	55	131	117.52
5	41	6.50	60	140	148.88
10	50	9.12	65	149	187.10
15	59	12.67	70	158	233.31
20	68	17.36	75	167	288.76
25	77	23.51	80	176	354.87
30	86	31.51	85	185	433.19
35	95	41.78	90	194	525.47
40	104	54.87	95	203	633.66
45	113	71.36	100	212	760.00
50	122	91.98	...	...	.....

TABLE III.

Giving weight of water vapor in saturated air at different temperatures.

Temp. C°	weight water vapor, grams per cubic meter.	Temp. C°	weight water vapor, grams per cubic meter.
0	4.83	40	50.76
5	6.77	50	82.45
10	9.33	60	129.44
15	11.49	70	199.02
20	17.16	80	291.04
30	30.11	100	589.83

TABLE III A.

Giving weight of water in half saturated air at different temperatures.

Temp. C°	weight water, vapor grams per cubic meter	Temp. C°	weight water vapor grams per cubic meter
0	2.47	40	25.38
5	3.38	50	41.22
10	4.66	60	64.72
15	5.79	70	99.51
20	8.58	80	145.52
30	15.05	100	294.91

TABLE IV.

Giving the weight of water vapor which 1 cubic metre of air can carry from a dryer, leaving at the different temperatures, entering at 10°C and 75% humidity.

Temp. C°	weight water vapor grams per cubic meter	Temp. C°	weight water vapor grams per cubic meter
10	2.33	50	76.34
15	5.62	60	123.53
20	10.41	70	193.29
30	23.59	80	285.47
40	44.45	100	584.57

TABLE IV A.

Giving weight of water which 1 cubic metre of half saturated air can carry from a dryer at the given temperatures, entering at 10°C and 75% humidity.

Temp. C°	weight water vapor grams per cubic meter	Temp. C°	weight water vapor grams per cubic meter
10	—2.34	50	37.12
15	—1.05	60	58.81
20	1.83	70	93.78
30	8.53	80	139.95
40	19.07	100	289.65

TABLE V.

Giving volume of air necessary to carry out water from 1000 brick, of 9 pounds wet weight and 22½% water. Air is heated up from 10°C and 75% humidity.

Temp. C° entering Dryer	Temp. C° leaving dryer.	Cubic meters air saturated.	Cubic meters air half-saturated.	weight dry air in 1 cubic meter saturated air.
15	10	396,566	Impossible	1.233
28	15	164,412	Impossible	1.205
43	20	88,770	504,918	1.777
80	30	39,169	108,558	1.116
157	40	20,787	48,453	1.046
260	50	12,103	24,892	0.960
452	60	7,479	15,711	0.852
775	70	4,776	9,852	0.712
1520	80	3,226	6,603	0.532
....	100	1,580	3,190	.....

TABLE VI.

Giving dimensions of inlet and outlet of various sized fans.

Diameter of Fan in inches.	Inlet		Outlet	
	Diameter in inches	Area in sq. in.	Size in inches.	Area in sq in.
50	20	314	17 x 17	289
60	23	415	20½ x 20½	420
70	26	530	24½ x 24½	500
80	30	706	27 x 27	729
90	34	907	30½ x 30½	930
100	38	1134	34½ x 34½	1188
110	42	1385	37½ x 37½	1406
120	46	1661	41½ x 41½	1722
140	53	2206	48 x 48	2304
160	60	2827	54 x 54	2916
180	68	3631	60 x 60	3600
200	76	4536	66 x 66	4356
220	84	5541	72 x 72	5184
240	92	6648	78 x 78	6084
260	100	8754	84 x 84	7056
280	108	9161	90 x 90	8100
300	116	10568	96 x 96	9216

TABLE VII.

Giving speeds and capacities in cubic feet per minute of fans, at varying revolutions, and H. P. required.

R. P. min.	Fan diameter in inches.	50	60	70	80	90	100	110	120	140	160	180	200	220	240
100	Cu. Ft.	682	1121	1870	2652	3840	5472	6385	9565	14916	20750	30221	41608	55201	71941
	H. P.	.150	.222	.370	.476	.672	1.01	1.37	2.03	3.46	5.47	7.7	12.0	17.1	25.1
125	Cu. Ft.	852	1402	2338	3158	4809	6844	7992	11945	18645	27170	37767	52610	68997	99910
	H. P.	.175	.284	.439	.588	.934	1.34	2.06	2.90	5.00	8.15	12.5	19.3	29.2	43.5
150	Cu. Ft.	1023	1681	2805	3979	5760	8110	9580	14360	22374	32610	45325	62412	82811	108120
	H. P.	.200	.325	.531	.756	1.27	1.86	2.74	3.90	7.22	11.3	19.6	32.1	46.2	68.6
175	Cu. Ft.	1194	1962	3274	4622	6729	9594	11200	16715	26100	38043	52883	72814	96626	126089
	H. P.	.225	.393	.647	1.01	1.74	2.46	3.55	5.52	9.91	17.3	27.9	44.2	67.1	103.0
200	Cu. Ft.	1364	2242	3740	5304	7690	10960	12830	19150	29850	43520	60442	83231	110422	143902
	H. P.	.262	.478	.855	1.26	2.05	3.16	4.69	7.01	13.3	23.7	39.2	62.1	96.8	154.5
225	Cu. Ft.	1534	2523	4207	5969	8655	12334	14385	21500	33560	48680	68000	93634	124217	.....
	H. P.	.300	.581	1.03	1.57	2.61	4.09	5.95	9.29	17.0	31.1	52.8	87.9	142.5	.....
250	Cu. Ft.	1706	2793	4675	6332	9600	13705	16000	23950	37310	54200	75558	104036	.....	.....
	H. P.	.375	.684	1.22	1.79	3.32	4.97	7.44	11.6	22.5	41.2	71.7	121.4	.....	.....
275	Cu. Ft.	1876	3083	5142	7294	10578	15773	17394	26278	41030	58328	83104	.....	.....	.....
	H. P.	.436	.821	1.45	2.35	3.92	6.09	9.09	14.5	29.4	54.7	89.3	.....	.....	.....
300	Cu. Ft.	2046	3363	5610	7957	11520	16250	19200	28800	44750	63629	.....	.....	.....	.....
	H. P.	.500	.975	1.73	2.86	4.63	7.44	11.4	18.1	37.5	69.3	.....	.....	.....	.....
350	Cu. Ft.	2387	3923	6545	9282	13410	19110	22395	33400	52206	.....	.....	.....	.....	.....
	H. P.	.663	1.28	2.38	3.89	6.65	10.7	17.2	28.3	55.8	.....	.....	.....	.....	.....
400	Cu. Ft.	2729	4384	7480	10620	15400	21950	25574	38300	.....	.....	.....	.....	.....	.....
	H. P.	.750	1.70	3.19	5.04	9.34	15.3	25.2	39.2	.....	.....	.....	.....	.....	.....

TABLE VIII.

Showing losses of heat units per cubic meter of escaping air due to sensible heat of the air, and not including losses by water vapor, etc. Air heated up from 10°C and 75% humidity.

Temp. C°	Dry air in cubic meter saturated air.	Heat units carried out in 1 cubic meter of saturated atmosphere.	Heat units brought in by same wt. of air entering at 10° and 75% Humidity.	Net loss per cubic meter due to increased temperature of air.	Heat units carried out by 1 cubic meter half-saturated atmosphere.	Heat units brought in by same weight of air entering at 100° C and 75% Humidity.	Net loss per cubic meter due to increased temperature of air.	Heat units carried out per cubic meter if air were dry.
10	1.233	2.92	2.92	.....	2.94	2.94	.....	2.95
15	1.205	4.27	2.85	1.42	4.32	3.24	1.08	4.37
20	1.177	5.58	2.79	2.79	5.64	2.82	2.82	5.71
30	1.116	7.93	2.64	5.29	8.71	2.70	5.41	8.28
40	1.046	9.92	2.48	7.44	10.30	2.56	7.74	10.68
50	0.960	11.37	2.27	9.10	12.14	2.43	9.71	12.93
60	0.852	12.12	2.02	10.10	13.58	2.26	11.32	15.05
70	0.712	11.81	1.68	10.13	14.42	2.06	12.36	17.04
80	0.532	10.08	1.26	8.82	14.52	1.81	12.71	18.92
90	.....	.....	....	.....	.....	....	.....	18.40
100	.....	.....	....	.....	.....	....	.....	.....

TABLE IX.

Giving volume of air required and heat consumption for 1000 brick, weighing 9 pounds wet weight and containing 22½% water. Air entering dryer is heated up from 10°C and 75% humidity.

Temp. C° entering.	Temp. leaving.	Heat units in evaporating water	Heat units in clay.	Heat units in cars.	Heat loss by radiation.	Heat units in escaping air.	Total heat units.	Coal required in lbs. estimated at 7000 Cal per unit weight of coal.	Volume of air in cubic meters.
28	15	562,120	3,756.4	193.89	56,607	240,006	862,683	271.04	167,837
43	20	563,592	7,512.9	387.78	57,149	274,601	903,242	283.20	98,072
80	30	566,444	11,269.3	775.56	57.848	258,443	894,779	281.20	48,855
157	40	569,204	18,782.2	1,163.34	58.914	192,577	840,640	264.22	25,884
260	50	571,964	26,295.1	1,551.12	59.981	125.088	784,879	246.66	13,746
452	60	574,816	33,808.0	1,938.90	61,056	85,698	757,317	238.04	8,485
775	70	577,576	41,320.9	2,226.68	62,112	58,176	741,411	232.76	5,743
1520	80	580,428	48,833.8	2,714.46	63,187	34,327	729,490	229.24	3,892
....	90	583,188	56,346.7	3,002.24	64.253	.....	.....	.....	.....
....	100	586,040	63,859.6	3,390.02	65,229	.....	.....	.....	.....

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